JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 31 August 1938 No. 4

CONTENTS

American Association of Economic Entomologists

Paper-Reading Session, Fiftieth Annual Meeting, Indianapolis, Ind., December 27–31, 1937

On Certain Habits of Elm Bark Beetles, B. J. KASTON and D. S. RIGGS 467

Field Notes on the Life History of *Hylurgopinus rufipes* (Eich.), CHARLES H. MARTIN 470

Effective Duration of Toxicity to the Mexican Bean Beetle of Derris Deposits on Foliage, J. N. TODD 478

New Facts Concerning Cryolite Spray Residues, S. MARCOVITCH and W. W. STANLEY 480

Soybean Flour as a Spray Material, M. D. FARRAR and W. P. FLINT 482

Potato Spraying Experiments in North Dakota, J. A. MUNRO and LOUIS A. SCHIFINO 485

Preliminary Studies of Wireworms Affecting Potato Tubers in North Dakota, J. A. MUNRO and LOUIS A. SCHIFINO 487

Control of Onion Thrips, NEELY TURNER and G. L. WALKER 489

Tests of Certain Materials as Controls for the Tomato Psyllid, *Paratrioza cockerelli* (Sulc.), and Psyllid Yellows, GEORGE M. LIST 491

Two Years of Study of the Effects of Root Nematode on the Yield of Canning Tomatoes, G. A. FICHT 497

Notes on the European Pine Shoot Moth in Connecticut, R. B. FRIEND, G. H. PLUMB and H. W. HICOCK 506

Insecticides Applied by Autogiro to Control Cankerworms Infesting Forested Areas, CLYDE C. HAMILTON 513

Observations of Grasshopper Parasitism in 1937, WILLIAM P. HAYES and J. D. DECOURSEY 519

Pacific Slope Branch

Paper-Reading Session, Twenty-Second Annual Meeting, Denver, Colo., June, 1937

Some Problems of the Annual Grasshopper Survey, ROBERT L. SHOTWELL 523

Current Contributions

The Host Plants and Parasites of the Cowpea Curculio and Other Legume Infesting Weevils, THEODORE L. BISSELL 534

A Preliminary Study of the Biology of *Scolytus sulcatus* LeC., L. L. PECHUMAN ... 537

Scientific Notes 544
Editorial 548
Reviews 549
Obituary 549
Current Notes 550
Horticultural Inspection Notes 477, 488, 518, 522, 533, 536

NOTICE TO SUBSCRIBERS

ENGRAVINGS of illustrations which have appeared in Volume 30 of the JOURNAL OF ECONOMIC ENTOMOLOGY may still be purchased by the respective authors or their representatives at one-half cost price. Engravings in the current issue are available under the same terms. This publication reserves the right to destroy those not ordered within 30 days from date of issue.

Orders to ship engravings to authors should be sent to the Editor, at Urbana, Illinois, from whom cost prices may be obtained. Authors will be billed by the Business Manager of the Association for purchased engravings plus mailing charges.

This regulation does not apply to engravings for articles for which the costs of publication have been paid by authors or their representatives. Such engravings will be shipped collect to authors at their discretion if ordered within 30 days from date of publication; otherwise they will be destroyed.

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 31 August 1938 No. 4

On Certain Habits of Elm Bark Beetles

B. J. KASTON and D. S. RIGGS, *Connecticut Agricultural Experiment Station, New Haven*

As is well known, before building a brood gallery under the bark of a weakened or sickly elm, the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, feeds for a time on the twigs of healthy trees. It has been shown that in this manner a healthy tree can be inoculated with the causal organism of the Dutch elm disease. Whether or not the native elm bark beetle, *Hylurgopinus rufipes* (Eich.), feeds on such twigs has long been a question of interest. Instances of such feeding were found only occasionally in the field. Experiments during the 1935 season showed that when beetles were enclosed in a cage containing only freshly cut twigs they made feeding tunnels similar to those of *S. multistriatus*. But when freshly cut logs of three to six inches diameter were provided also the insects tended to attack the latter rather than the twigs. Some entered these logs within less than one day after emerging as adults.

Accumulations of frass in crevices of the outer bark lead the investigator to suspect that the beetles have burrowed in to build egg galleries. But if such a place is investigated thoroughly it will be found that, instead of an entrance hole leading to the wood surface, there is a shallow tunnel more or less parallel to the surface, just under the outer bark, fig. 1. Many such bark tunnels were observed beginning about July 24, at which time their significance was not apparent. It was found that these bark tunnels were deserted later and true entrance holes leading to egg galleries were built in the logs. One log placed in a cage with 100 beetles on August 9 was examined on September 11. On the latter date, 74 beetles were recovered, of which 9 were in bark tunnels. There were in addition 47 unoccupied bark tunnels as well as 16 brood galleries under the bark.

In 1937 the first bark tunnels were observed in the field on July 22, which was shortly after the young beetles had started emerging. From July 30 to September 3, various live elms were examined

FIG. 1.—Surface view of a portion of trunk showing bark tunnels, natural size.

at intervals of three or four days. During this period notes were taken on a total of 291 bark tunnels in the tops, trunks and exposed roots. The average length of tunnels was 3.4 millimeters, and over 90 per cent lay in part in the inner bark. Some approached quite close to the surface of the wood, fig. 2; however, none was found that attained the sapwood as re-

ported by Becker (1935). While some of the tunnels had been deserted by the beetles, 51.5 per cent were still occupied. The direction of tunneling varied, with 45

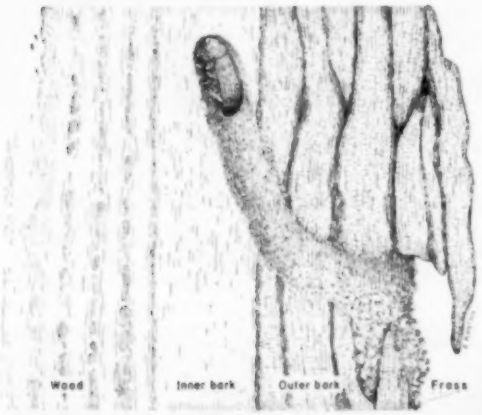

FIG. 2.—Longitudinal section through a bark tunnel in a log showing the relation to outer and inner bark layers and to wood. (Semi-schematic, about four times natural size.)

per cent up, 11.3 per cent down, 5.5. per cent transverse, 34.3 per cent oblique. In 3.8 per cent the direction could not be determined as apparently the beetles had not progressed far enough. The ratio of occupied to deserted tunnels for this particular group is rather high. On September 15, of 150 tunnels examined, only 38 were occupied, or 25.3 per cent. Many random samples gave even lower ratios.

Though the bark tunnels are found most commonly on the trunk, they occur from the ground level all the way up into the smaller limbs. Fig. 3 shows a few in a one-inch branch, and they have been seen in a five-eighths-inch branch. To obtain some idea of the density of beetle population at various levels on the trunk and leaders, a healthy tree was selected at random from among those standing in an area where beetles had emerged. The tree was quite straight, had a D.B.H. of 10 inches and presented a fairly even surface up to about 48 feet from the ground. Five levels were chosen at intervals of approximately 10 feet. At each level a section of bark 18 inches in height was carefully gone over, and only those tunnels noted which gave evidence of being recently made, *i.e.*, not from the previous years.

The results of our observations made from September 6 to 9 inclusive are shown in table 1. If these areas sampled are any

FIG. 3.—Small branch with bark tunnels, natural size.

indication, there must be a very large number of tunnels in the entire tree. The estimate given for the trunk includes only one of the main leaders. The density of these tunnels is greatest in the area between 12 and 33 feet above the ground. The percentage of occupied tunnels is lowest in this same region. This would indicate that this part of the tree is preferred by the first beetles to emerge from breeding places. The upper and lower regions are attacked by the later emerg-

Table 1.—Bark tunnels in a healthy elm tree at various levels above the ground.

HEIGHT ABOVE GROUND	DIAMETER IN CENTIMETERS	TOTAL NUMBER	BARK TUNNELS; DENSITY PER SQUARE DECIMETER	OCCUPIED	
				NUMBER	PER CENT
2 feet 6 inches to 4 feet	26.8	49	1.3	15	30.6
12 feet 6 inches to 14 feet	20.4	423	14.4	50	11.8
22 feet 6 inches to 24 feet	14.1	266	13.8	29	10.9
31 feet 10 inches to 33 feet 4 inches	12.0	232	13.7	22	9.5
42 feet 2 inches to 43 feet 8 inches	6.2	58	6.6	10	17.2
Whole trunk (estimated) Bottom	*30.0*	*6753*	*8.3*	*818*	*12.1*
Top	*5.0*				

ing beetles, after some of the early ones have left the live tree to find suitable breeding places.

The making of bark tunnels by *H. rufipes* is considered by us to be analogous to the crotch and twig feeding of *S. multistriatus*. However, we did find a very few instances in which the latter species made bark tunnels, just as, conversely, occasional twig and crotch feeding by *H. rufipes* has been noted.

We, as well as others, have observed that adult beetles overwinter in similar bark tunnels in healthy trees. The question arises: Is there any difference between hibernating tunnels and tunnels made from July to September presumably for feeding? We have made observations at regular intervals from July through December and are inclined to believe that there is no fundamental difference. The beetles emerging early make their bark tunnels and then leave to construct egg galleries elsewhere.

Those emerging later may construct bark tunnels late enough in the season to find their activity considerably retarded by the low temperatures prevailing during constantly increasing portions of each day. Hence they do not leave to construct brood galleries, and their feeding tunnels now become their hibernating tunnels. The latter are, in general, of greater length than the former.

We have noticed also that the ratio of unoccupied tunnels in the smaller branches, where the bark is thin, increases during October and early November. We believe this to indicate that some of the beetles that feed there leave to seek thicker bark in which to hibernate. Observations during the fall indicate that some young adults may emerge from breeding material as late as October 30. These apparently make their tunnels where the bark is thick.

How to tell when the beetles are still feeding or have started hibernating is another question for which we have tried to find the answer. Becker (1935) reports late September as the time when first signs of hibernation were noticed, but he was then unaware that bark tunnels could be made before that time in the same places. To determine whether beetles were active and feeding, we dissected out the alimentary canal and examined the ventriculus for food. Although we found some beetles in their bark tunnels already inactive and with empty ventriculi on October 3, we found many still active and feeding right through to the end of October. It is evident that the prevailing local temperatures influence their activity on any given day, and that some of the beetles could have backed out of tunnels made in September or earlier to construct new ones in which to hibernate.

The importance of this bark tunneling habit in relation to the spread of the Dutch elm disease can be easily understood. The several diseased trees taken down at Old Lyme, Conn., during the summer of 1935 showed bark tunnels presumably made by beetles which had emerged from the diseased tree of 1934. This latter contained large numbers of *H. rufipes* brood galleries with many spores of the fungus. It is highly probable that inoculation occurred through one of these bark tunnels. The same may be assumed for the single diseased tree at Branford, 1936. As in the case of the Old Lyme trees, no crotch or twig feeding scars could be seen, but bark tunnels were found.—1-7-38.

SUMMARY.—The native elm bark beetle *Hylurgopinus rufipes* (Eich.), before constructing brood galleries in sickly elms first makes feeding tunnels in healthy elms. These tunnels are in the bark alone and do not touch the surface of the wood. The trunk of the tree is preferred, but tunnels may be found from the exposed roots all the way up to branches less than an inch in diameter. Usually, more than one feeding tunnel is made by each beetle. Bark tunnels made for hibernation tend to be longer, and are more often in thicker bark, than the otherwise similar feeding tunnels. It is believed that the latter are analogous to the well-known crotch and twig feeding injuries of *Scolytus multistriatus* Marsham, and hence important in relation to the spread of the Dutch elm disease.—1-7-38.

LITERATURE CITED

Becker, W. B. 1935. Some observations on the overwintering habits of the American elm bark beetle, *Hylurgopinus rufipes* (Eich). JOUR. ECON. ENT., **28**(6):1061–5. 2 figs.

Field Notes on the Life History of *Hylurgopinus rufipes* (Eich.)

CHARLES H. MARTIN, *Cornell University, Ithaca, New York**

During the past three years several papers (see literature cited) have appeared with notes on the life history of *Hylurgopinus rufipes* (Eich.), the native elm bark beetle. Some of the papers contain brief field or laboratory notes incidental to the work reported, while only two have given detailed data about particular phases of the life history. This paper presents the life history data the writer has collected over a three-year period.

The data were collected at Patterson, N. Y., which is on the eastern edge of the Hudson Valley district, Austral in character, and very near the southern edge of the Taconic district, Canadian in character, according to Forbes (1928). Because the two zones approach one another in the vicinity of Patterson, this region is more Transition in character. For this reason the general outline of *Hylurgopinus* life history in other zones will probably more or less differ from the one described here.

METHODS OF INVESTIGATION.—The data were collected in 1935, 1936 and 1937. Throughout this period several hundred American elm logs were cut each year at approximately bi-weekly intervals during the season of beetle activity. All logs were kept up to the time of examination on racks which consisted of pairs of horizontal bars nailed to four posts 3 feet high. The logs cut in 1935 were 3 feet long while those cut in 1936 and 1937 were 2½ feet long. All logs had an average diameter of 5 to 6 inches.

Each cutting of 12 to 80 logs was put in a different location in 1935, as described by Martin (1936), while in 1936 and 1937 40 logs from each cutting were divided equally among four stations used in 1935, one being in deep shade, two in medium shade and one without shade. The stations were within 40 to 100 yards of one another.

In 1935 and 1936 the entrance records were taken irregularly during the season, while in 1937 they were taken at weekly intervals throughout the season. From May 4 to June 15, 1937, 56 logs per week were examined, while 20 to 30 per week were examined the rest of the season.

In 1935, counts of the number of eggs and larvae per maternal tunnel were made throughout the summer by stripping two logs from each cutting each week. Whenever possible, 20 tunnels from each log were examined for the April 25 and May 15 cuttings. At the same time the number of maternal tunnels per log was recorded. The number of *Hylurgopinus* tunnels was so low in logs cut after May 15 that often none was available for records. In 1936 and 1937 the number of maternal tunnels and the number of larvae were recorded.

Records of the number of maternal tunnels per log were made for the 1936 and 1937 cuttings some time after the beetles had definitely ceased coming to the logs. No counts of eggs and larvae were made in 1936 and 1937, except in the case of overwintering larvae.

LIFE HISTORY.—During the winter at Patterson, N. Y., approximately 80 to 90 per cent of the entire *Hylurgopinus* population is in the adult stage and the rest in the larval stage. The main population emerges from hibernating quarters in May and enters suitable bark to lay eggs. The larvae first appear shortly before mid-June in some years and earlier in others. Most of the larvae pupate about the last part of July and the first part of August. The main population adults emerge from the first part of August until the end of the season, the largest numbers appearing toward the latter part of August. Apparently they seek hibernating quarters immediately.

During the summer a small number of adults constantly enter the trap-logs. As will be shown later the adults from the first eggs enter the same summer; adults from the last eggs enter the following summer. Also, summer adults rise from diapause larvae which probably hatch from eggs laid at any time of the season. Lastly, the eggs of summer adults give rise to adults the following summer. Most

* The writer is indebted to Dr. P. A. Readio and Dr. D. L. Collins for critical reading of the manuscript.

of the summer adults are in the larval stage during the winter.

Fig. 1 traces the cycles of the two groups. A heavy line in the upper part of the figure traces the life history of the main population, and light lines trace the life history of the secondary population of overwintering larvae and summer adults.

TIME OF APPEARANCE OF ADULTS.—Studies of the relative number of *H. rufipes* adults appearing at different times of the year were made by comparing the entrance records of 1937 in fig. 2. In this figure the average number of entries for all cuttings examined is contrasted with that cutting which had the greatest number of entries.

Also, the infestations of the sucessive cuttings of each year in table 1 indicate roughly the fluctuations of the populations during each year since, after each cutting had been infested, it progressively became less attractive until the beetles ceased entering. The attractive period lasted from two to nine weeks, with only a few stragglers entering during the last part of the longer periods. The period varied at different times of the season and from season to season. Data on the attractive period will be reported later.

The discussion of the seasonal fluctuations of the appearance of the adults falls into three parts: the first appearance of

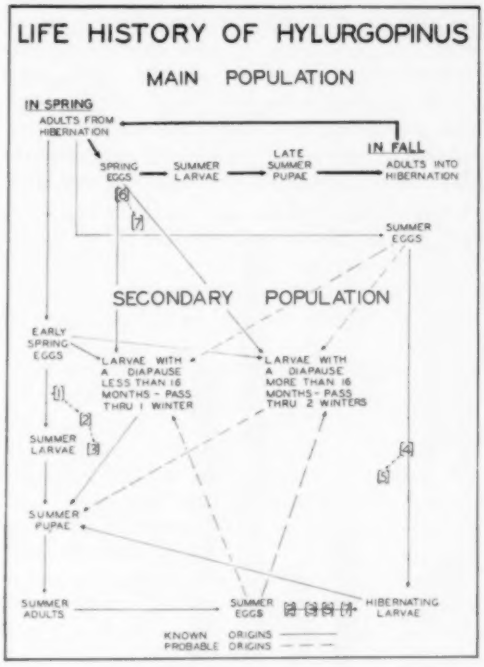

FIG. 1.—The interrelated life cycles of the main population and the secondary population of *Hylurgopinus rufipes*.

Table 1.—Average number of *Hylurgopinus* maternal tunnels per log per cutting and for season.

DATES OF CUTTINGS	YEAR OF CUTTING AND THE DEGREE OF SHADE								
	1935			1936			1937		
	Deep Shade	Medium Shade	No Shade	Deep Shade	Medium Shade*	No Shade	Deep Shade	Medium Shade*	No Shade
Late winter	40.5			70.6	68.3		181.3	163.7	134.5
					71.6			165.5	
May 15	50.0			77.5	37.0		124.2	161.6	42.8
					16.5			166.1	
May 30		5.0		8.0	29.6		21.4	13.7	4.4
					22.8			10.3	
June 14	1.1			3.8	28.9	23.4	56.9	22.8	8.6
					44.1			27.5	
June 28		2.8		3.2	17.6	5.0	16.2	6.8	1.2
					31.0			6.4	
July 17			0.8	0.1	1.8	0.2	2.4	1.2	0.2
					1.9			1.0	
Aug. 2		0.5		0.4	2.4	0.0	0.0	0.3	0.0
					0.2			0.7	
Aug. 17		0.5		0.2	1.0	1.2	0.0	0.0	0.0
					1.8			0.1	
Aug. 30		0.9		0.0	0.1	0.0	0.0	0.0	0.0
					0.0			0.0	
Total tunnels for season				*1638.0*	*1936.0*		*4024.0*	*3701.0*	*2414.0*
					1899.0			*3778.0*	
Average number tunnels per log for season				*20.5*	*24.2*		*50.3*	*46.3*	*30.2*
					23.7			*47.2*	

* In 1936 and 1937 two medium shade locations were used; the infestation for each station is tabulated separately.

the beetles, the main population peak and the secondary population peak ending in the decline of the adult population.

The time the adults begin to enter logs seems to depend a great deal upon weather. In 1935, a late spring, no *H. rufipes* were observed at the logs until May 25, while in 1936 and 1937, when the seasons were more advanced, some adults entered the logs to lay eggs before May 1. Becker (1935) found them first entering trap-logs and making egg tunnels on May 20, 1935, at Amherst, Mass.

There was a sharp main population peak and also a secondary one of *H. rufipes* adults in 1937. The greatest numbers of adults came to the logs between May 19 and 26. During June the numbers dwindled considerably as compared with the numbers which came during May, fig. 2. The general average of 16 entries per log for the first week of June drops to 0.9 entry per log for mid-June. The secondary peak appeared at the end of June when there was a general average of 3.8 *H. rufipes* entries per log. During the rest of the season the numbers became smaller and smaller until they ceased entering in September.

The log infestation data of 1937 in table 1 also indicate population trends similar to those established by the 1937 entry data, although their exact time is not apparent. Likewise, the log infestation data of 1935 indicate the probability of a primary and a secondary peak for this year. The first two cuttings were highly infested, indicating a high population at the beginning of the season. Then there was a progressive dwindle of infestation in the May 30 and June 14 cuttings. The June 28 cutting had an infestation that was significantly higher than the infestation of either the June 14 or July 17 cutting.

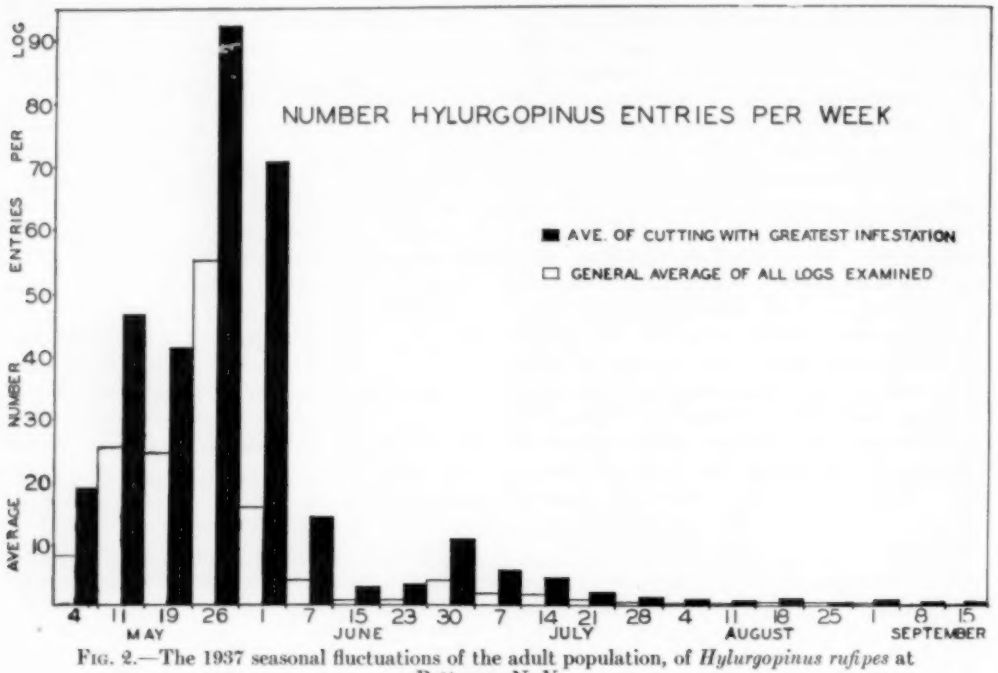

FIG. 2.—The 1937 seasonal fluctuations of the adult population, of *Hylurgopinus rufipes* at Patterson N. Y.

The infestations of the 1936 cuttings indicate a high, early-season high population and a progressive dwindle as the season advances, but the secondary peak is not so evident as in the 1935 and 1937 data.

INFLUENCE OF LIGHT INTENSITY ON INFESTATION.—When these investigations were first begun (see Martin 1936) *H. rufipes* appeared to favor shaded logs. This seemed true since the heaviest infestations were found on the shady side of logs and in the logs in deep shade. The data of 1936 and 1937 corroborate the statement that *H. rufipes* infestation is

usually heaviest on the shaded side, but the degree of shade in which the log is placed does not seem to influence infestation. This fact seems to be established when comparisons of the differences of infestations of logs in the two degrees of shade are made cutting by cutting for 1936 and 1937; also when seasonal averages for the two degrees of shade for the same year are compared. Significance has been tested by the analysis of the variance.

In making these comparisons it was found that for either year there were often significant differences in infestation for the same cutting between the two degrees of shade. However, these differences were not consistent from cutting to cutting nor from year to year. In 1936 the logs in medium shade generally had the highest infestations, while in 1937 the logs in deep shade generally had the highest infestations. When the two degrees of shade are compared by seasonal averages for the same year the averages differ but slightly. Hence, apparently some other factor than shade caused the significant differences between the various cuttings in the two degrees of shade.

A possible explanation for the infestation differences which have just been discussed is that *Hylurgopinus* adults do not travel very far, so that infestation of a log will depend upon its proximity to the beetle hibernation quarters.

INFLUENCE OF TEMPERATURE ON INFESTATION.—Graham (1924) showed that temperature was a factor influencing the distribution of bark beetles in pine logs. It is also a factor affecting the infestation of *Hylurgopinus* in elm logs placed in direct sunlight, the effect of temperature becoming more apparent in heavily infested logs than in lightly infested ones. The area of the log most exposed to the sun becomes hot enough to kill the *Hylurbopinus* attempting to enter this region. During July and early August the temperatures often cause the bark to shrink and split. The area affected may be from one-third to one-half the phloem area, depending upon the size of the log and the amount of shade cast by adjacent logs. Most of the beetles avoid this area so that it is always with little or no infestation, while the shaded area may become heavily infested. For this reason the infestation of the log is decreased in proportion to the area which is too hot for the beetles to enter. Even after the shaded area has become heavily infested the temperature of the entire log may become high enough to kill all stages of *Hylurgopinus* in even the shaded part. The temperature factor explains, at least partially, why in 1937, the infestation of logs in the sun was consistently lower than of those in the shade.

BEETLE ENTRY INTO LOGS.—The beetles enter the logs rather slowly, sometimes being in sight in the spring for two or three days before disappearing. In a few cases *Hylurgopinus* was found using *Scolytus* entry holes to begin its own tunnels.

NUMBER OF EGGS PER TUNNEL.—Egg laying and tunnel making are two closely related activities. Usually there are two, sometimes three, maternal galleries of unequal length extending in different directions across the grain of the wood from a single entrance hole. The tunnels are usually between the phloem and xylem; when the phloem of tree trunks is about one centimeter thick the maternal tunnel may be made only in the phloem, not contacting the xylem. The combined length of the two tunnels may be as long as 70 millimeters. The average length of 548 tunnels measured in 1935 was $35.5 \pm .36$ millimeters (p.e.); the average number of eggs per tunnel was $56.1 \pm .77$ eggs.

The first eggs are laid closely together on both sides of the tunnel but as the female becomes spent the eggs are laid farther and farther apart, the distance between the eggs often being 5 or 6 millimeters. The number of eggs in 62 tunnels, averaging between 25 and 30 millimeters in length, ranged from 25 to 110 eggs; in 70 tunnels, averaging from 35 to 40 millimeters in length, the range was 40 to 125 eggs. The correlation coefficient between tunnel length and number of eggs was .360 for 548 tunnels, a highly significant value.

LENGTH OF OVIPOSITION PERIOD.—The data obtained by the weekly stripping of the April 25 to May 15 cuttings give an estimate of the oviposition period, this value being for the population as a whole and not as an average of a series of observations made for individual insects. This estimate has been obtained by plotting the average number of eggs per maternal per week (unhatched eggs+larvae) and

also the average number of unhatched eggs per tunnel per week in fig. 3. These data are fairly homogeneous because the majority of adults entered the logs within a very short time.

Egg laying was begun by the majority of beetles about a week or less before the first counts presented in the figure. The ment of the unhatched egg curve from July 17 through 31 might be indicative that they did. Also, this segment might be the result of egg laying by females entering the logs sometime after the majority had entered.

THE EGG SEASON.—The eggs of the main population were present from late

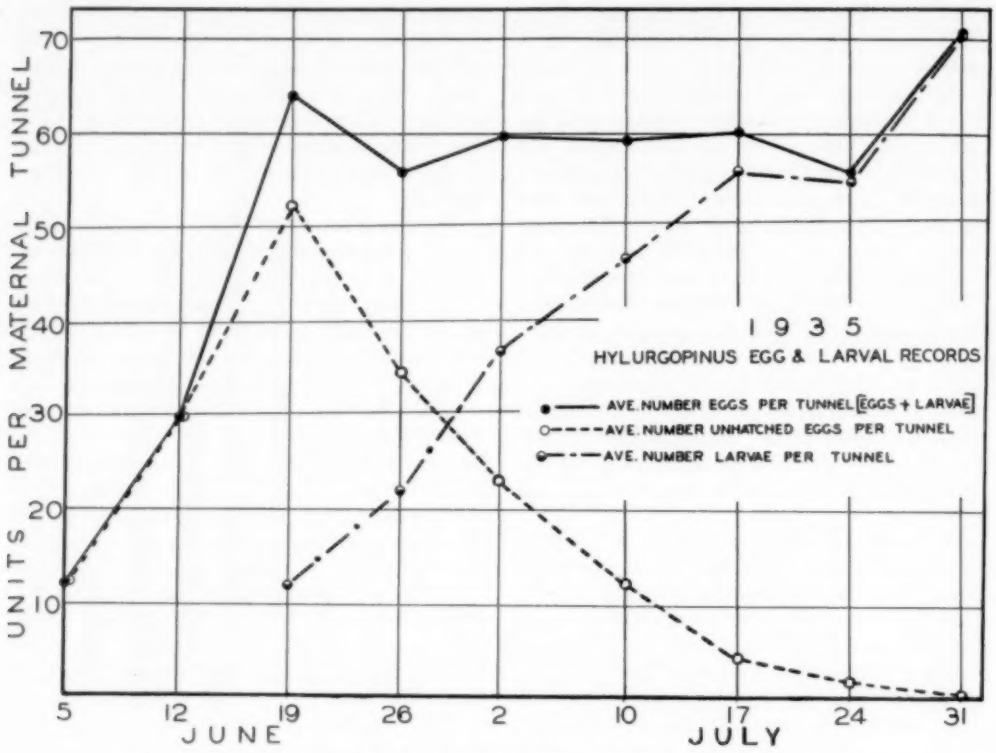

FIG. 3.—*Hylurgopinus rufipes* egg and larval data for 1935 at Patterson, N. Y.

number of eggs per tunnel increased until June 19. At this time the average of 64.1 ± 2.63 eggs per tunnel exceeded the general average of $56.1 \pm .77$ for the season. With the exception of the July 31 average, the rest fell close to that for the season. Also, at this time the number of unhatched eggs reached their peak and on the following week there was a sharp drop in their numbers. From these data it is evident that most of the eggs were laid within a period of three weeks.

While most of the eggs were laid by June 19, yet live females with mature ova were found as late as July 23; live females without mature ova were found until August 1. Whether or not the females laid these eggs is not known. The "tail" seg-

May until August 1, 1935, the largest number being found around June 19, just at the time the larvae began to hatch.

LARVAE, PUPAE AND EMERGENCE OF FALL ADULTS.—Collecting data on the larval period of the main population was difficult. Often the *Hylurgopinus* colonies were partially or completely obliterated by *Saperda* larvae, which outnumbered the *Hylurgopinus* colonies several times. Data were taken on the length of the longest larval tunnel per maternal tunnel per week but the progress of the larva could be followed for only a short distance. After tunneling the phloem-xylem surfaces for distances of 25 to 70 millimeters, the larvae often disappear beneath the phloem surface. Also some

colonies of larvae seem to grow more rapidly than others in the same log so that larval tunnel data are not comparable. Because of the extreme variation between individuals and between colonies the averages of the longest larval tunnels per week were of little value. Kaston & Riggs (1937) have published a paper on the larval instars of *Hylurgopinus*.

When *Hylurgiopinus* larvae have about reached maturity many of the nearly grown *Saperda* larvae in the same logs have reached a length of two to three centimeters. By this time the tunneling of both species has almost completely disintegrated the phloem. *Hylurgopinus* pupae then begin to appear, but it is usually impossible to associate them with their maternal tunnel. For this reason data on the abundance of last stage larvae and on the pupae are lacking.

Counts were made of the number of larvae per maternal tunnel per week during June and July. The averages are plotted in fig. 3 with the egg data.

The first larvae were found June 19, there being an average of 12 per maternal tunnel. Their numbers steadily increased until July 30, 93.8 per cent having hatched by July 17. A few larvae pupated in mid-July 1935, while in 1936 and 1937 pupae were found as early as July 9. These pupae were from larvae hatching from eggs laid early in the season. Pupae were first found in numbers on July 30. At this time it was estimated that there were one to five per maternal tunnel.

A few callow adults began to emerge the first week of August 1935; in 1936 and 1937 they were found emerging as early as July 20. Heavy emergence of adults did not take place until after mid-August in 1935, and a little earlier in 1936 and 1937. In 1935 a few of these came to the trap-logs and made winter tunnels similar to the ones described by Becker (1935) but the majority seemed to prefer hibernating quarters in live, standing trees. None came to the trap-logs in 1936 and 1937.

THE SECONDARY POPULATION.—As pointed out before, small numbers of adults which have been labeled as the secondary population or summer adults, continued to come to the trap-logs long after the spring emergence peak. Their numbers were extremely variable from year to year and from location to location. These adults rise, as shown in fig. 1, both from the main population and from the secondary population itself. The number coming from each source probably varies from year to year and is likely dependent on weather and upon the extent of larval mortality.

The sources of the secondary population are inferred to be as follows (each source is given the same number as that listed in fig. 1):

1. A few adults from eggs laid early in the season emerge in July of the same year.

2. Some of the adults of source 1 lay eggs which hatch too late for the larvae to become adults until the following summer.

3. The adults from source 2 would lay eggs giving rise to adults the second summer after the adults of source 1 had emerged.

4. Fig. 3 shows that some of the eggs of the main population do not hatch, at least in late seasons, until after July 10. At this time these larvae would have to compete for food with the older *Hylurgopinus* and *Saperda* larvae, especially in heavily infested logs, and it is doubtful if any would survive. Such must have been the case in the April 25 and May 15 cuttings where no early instar overwintering larvae were found either in the fall of 1935, or the following spring. In lightly infested logs these individuals might be able to survive and become adults the following summer.

5. Larvae from the eggs of the adults of source 4 would not become adults until the summer following the emergence of the adults of source 4.

6. Some larvae of the main population enter a diapause in which they remain for one or two winters. This fact seems quite probable for larvae from the eggs of the main population and probably would be true for other larvae, as indicated in fig. 1.

7. Larvae from the eggs of the adults of source 6 would not become adults until the summer following the emergence of adults from source 6.

Thus, it is evident that, with the exception of the adults coming from eggs laid early in the season, the adults appearing in the summer overwintered as larvae.

In order to learn of the abundance of overwintering larvae a supply of logs cut

April 25, May 15, and 30, June 14 and 28, 1935, were examined weekly in 1936 from May to September, and in 1937 during May and June. The results of the 1936 data are summarized in table 2. Since there was no difference in infestation between the April 25 and May 15 cuttings, and also the May 30 and June 14 cuttings, they have been averaged. While the same number of logs were examined for each cutting, fewer logs represent the later cuttings because many of the logs were without infestation.

The cuttings of May 30 and June 14 were infested for the most part by beetles entering during June. Judged from the oviposition period of the main population, most of the eggs in these logs were probably laid during June. There were 11.5 times more overwintering larvae in these logs than were in the first cuttings. Larvae were found in 42 per cent of the 14 logs infested. In these cuttings and also that of June 28, the progeny of any one female may develop to the adult stage the same season or may remain

Table 2.—The abundance of overwintering *Hylurgopinus rufipes* larvae.

Month Examined, 1936	Dates of the 1935 Cuttings								
	April 25 and May 15			May 30 and June 14			June 28		
	Maternal Tunnels	1935 Emergence Holes	Overwintering Larvae	Maternal Tunnels	1935 Emergence Holes	Overwintering Larvae	Maternal Tunnels	1935 Emergence Holes	Overwintering Larvae
May	401	1490	19	13	61	21	8	0	47
June	770	3375	25	34	87	10	25	11	102
July	170	820	2	39	90	0			
Aug.	115	91	2				3	4	0
Sept.	44	136	0						
Totals	*1500*	*5912*	*48*	*86*	*238*	*31*	*36*	*15*	*149*
Average per maternal tunnel		*3.9*	*0.032*		*2.7*	*0.37*		*0.41*	*4.1*

The number of overwintering larvae progressively increased from 0.032 larvae per maternal tunnel in the first two cuttings to 128 times this number in the June 28 cutting. At the same time the number of adults emerging from the logs decreased.

The eggs of the main population were laid in the April 25 and May 15 cuttings. The average number of larvae from these eggs going through the winter was 0.032. Overwintering larvae were in 21.9 per cent of the 32 logs examined. All the larvae found in these logs in 1936 were in the last instars. Callow adults and also pupae were found as late as August 9, 1936, which suggests that some of the larvae were in a diapause state.

Live larvae which had passed through a second winter were found in these logs in May and early June, 1937. After this time a few larvae were found which had presumably died by drowning. Frequent rains had kept the logs water-soaked most of the season. These larvae can be considered as having been in a diapause state.

larvae through the winter before becoming adults. Some of these larvae hibernate before reaching the last instars. The 1935 emergence holes in these two cuttings decreased as compared with the first two cuttings.

The June 28 cutting containing the eggs laid in July showed an increase of 11 times more overwintering larvae than were in the May 30 through June 14 cuttings. Many of the larvae in this cutting were found in the spring to be but half grown. Seven of the nine infested logs contained hibernating larvae. Again there was a decrease in the number of larvae emerging as adults in 1935. On June 8, 1936, callow adults were found in one of the logs of this cutting. A few were observed emerging July 1.

During all three years some *H. rufipes* adults emerged from the logs of the June 28 cutting the same year it was made but none emerged the same year of the mid-July cutting. Hence, sometime during this period the point is reached where the larvae from all the eggs laid pass through a winter before reaching the adult stage.

Quite a number of adults were observed emerging from the July-August cuttings around the first of July the following year, just at the time the secondary peak occurs.

NATURAL MORTALITY.—There are a number of causes for mortality. While predators and various parasites take a toll of adults and larvae, yet the adverse conditions of the log cause a much greater mortality. The data in table 2 give a measure of mortality in the April 25 and May 15 cuttings for all factors. Although the average number of eggs per tunnel in these cuttings was 56.1 eggs, yet the number of beetles emerging was only 3.9 adults per maternal tunnel. Thus, only 6.9 per cent of the eggs became adults. For all three years the mortality of larvae hatching during the summer was even greater, quite often being 100 per cent in many logs regardless of location. Undoubtedly the high mortality of the summer larvae prevents the appearance of a large summer population of adults.

SUMMARY.—The majority of *H. rufipes* adults come from hibernation during May, the peak occurring the last part of May. These adults lay the majority of their eggs in about three weeks. The first larvae hatch in mid-June; the last hatch the last part of July. Pupae appear in numbers around the last part of July and the first part of August. The peak of emergence of adults from these pupae is about mid-August. The adults apparently go into hibernation immediately.

Apparently if the logs are shaded, the degree of shade in which they are placed does not affect *H. rufipes* infestation. The logs in the sun reduce infestations because the part of the log exposed to the sun becomes hot enough to kill the beetles attempting entrance in this area.

Throughout the summer small numbers of adults enter the logs and lay eggs. Only a few of these adults can be considered as a true partial generation; these originate from eggs laid very early in the season. The rest arise from larvae which mature after passing through the winter. Some of the larvae overwinter because they hatch too late to do otherwise, while others probably are in a diapause state. Some larvae pass through a second winter but are not observed to emerge.

The average number of overwintering larvae from eggs laid by beetles entering logs in early May was found to be 0.032 per maternal tunnel, while 128 times this number from eggs laid by beetles entering in July overwintered.

Although the average number of eggs per maternal tunnel was $56.1 \pm .77$ eggs, yet there was an emergence of only 3.9 adults per maternal tunnel from eggs laid by adults from hibernation.—1-7-38.

LITERATURE CITED

Becker, W. B. 1935. Some observations on the overwintering habits of the American elm bark beetle, *Hylurgopinus rufipes* (Eich.) JOUR. ECON. ENT. **28**(6):1061–5. 2 figs.

Becker, W. B. 1937. Some notes on the tunneling habits of *Hylurgopinus rufipes* (Eich.). JOUR. ECON. ENT. **30**(2):375.

Collins, C. W., W. D. Buchanan, R. R. Whitten and C. F. Hoffmann. 1936. Bark beetles and other possible vectors of the Dutch elm disease *Ceratostomella ulmi* (Schwarz) Buisman. JOUR. ECON. ENT. **29**(1):169–76.

Forbes, W. T. M. 1928. Faunal districts. *In* M. D. Leonard, A list of the insects of New York. Cornell Univ. Ag. Exp. Sta. Memo. **101**:7–11.

Graham, S. A. 1924. Temperature as a limiting factor in the life of subcortical insects. JOUR. ECON. ENT. **17**(3):341–53. 2 figs.

Kaston, B. J., and D. S. Riggs. 1937. Studies on the larvae of the native elm bark beetle. JOUR. ECON. ENT. **30**(1):98–108. 7 figs.

Martin, Charles H. 1936. Preliminary report of trap-log studies on elm bark beetles. JOUR. ECON. ENT. **29**(2):297–306. 1 fig.

Readio, P. A. 1935. The entomological phases of the Dutch elm disease. JOUR. ECON. ENT. **28**(2):341–53. 2 figs.

THE SERVICES of Roy G. Richmond, formerly State Entomologist of Colorado, have been obtained by the Bureau of Entomology and Plant Quarantine. Mr. Richmond has been appointed as Associate Plant Quarantine Inspector on the Washington staff of the Division of Domestic Plant Quarantines.

Effective Duration of Toxicity to the Mexican Bean Beetle of Derris Deposits on Foliage*

J. N. Todd, *South Carolina Agricultural Experiment Station, Clemson*

The fact that rotenone insecticides deteriorate when exposed to sunlight has been known for several years (Jones *et al.* 1933). Experimental data to indicate the rate at which this action takes place are scant. In order to secure some information on this point, the experiments reported here were conducted at Clemson, S. C., during the summer of 1937.

Procedure.—The dust used in these tests was made by diluting powdered air-floated derris containing 5 per cent rotenone with cosmetic talc. A commercial insecticide mixer of the agitator type driven by an electric motor was used to prepare the dust. The components were agitated together for 15 minutes in order to secure an even mixture. Enough material was mixed at one time to supply the needs for the entire season. After being mixed, the insecticide was stored in water-proofed pasteboard cartons which had tight-fitting lids.

The derris for spray suspensions was obtained from the same lot as that used for the dust mixture. A suspension in tap water was made fresh for each application.

Bean plants for the tests were grown in eight-inch clay pots, each containing three healthy, vigorous plants at the time the tests were started.

The dust was applied with a hand-operated plunger duster. The spray was applied with a hand-operated, continuous-stream type sprayer. Special efforts were made to secure thorough application of the insecticides, and it is probable that a better application was obtained than would be possible under field conditions. Plants for a number of delayed tests were treated at the same time and with the same mixture of materials. After the insecticide had been applied, some of the potted plants were immediately taken inside the screened insectary and plunged the full depth of the pots in soil tables filled with moist sand where they were protected from direct sunlight and rain. The others were left exposed to prevailing weather conditions until put on test 3 to 20 days later. After the desired exposure in the open, these plants were placed in soil tables in the screened insectary as described above.

Tests were made immediately on the treated plants in the pots which had been set in the soil tables; 25 specimens of Mexican bean beetle, *Epilachna varivestis* Muls., (either larvae or adults) were caged on each pot of plants. The cages used were made of screen wire on sheet metal frames 14 inches in diameter and 18 inches high. The results of the tests were checked at the end of three days, and all the insects were removed from the plants. Beetles were placed on the shaded plants during more than one interval after the original application of derris, because the plants remained healthy and vigorous enough to afford sufficient foliage for the insects. The plants exposed to the sun were used for only one test. Check tests, in which untreated plants were used, were made for all the tests, and corrections were made in computing results for any mortality which occurred.

Insects for experimental work were collected in the vicinity of Clemson from bean fields in which no insecticide had been applied. After adults of the current season appeared, no overwintering adults were used, and at all times only those individuals which appeared healthy and vigorous were selected. No insects were used for more than one test.

No attempt was made to eliminate the factor of new growth on experimental plants after treatment, since the experiment was designed primarily to indicate the effective duration of derris under field conditions.

Results.—The figures presented in table 1 are representative of a large amount of data secured in these tests.

The data indicate the rate at which derris loses its toxicity for the Mexican bean beetle when exposed in thin films on bean foliage.

In table 1, it is apparent that bean foliage treated with 0.75 per cent rotenone

* Technical Contribution 55 of the South Carolina Agricultural Experiment Station.

dust and exposed to the sun retains some of its toxicity for the Mexican bean beetle over a period of 14 days. Even though this toxicity was apparent in the mortality of the insect, no indications of any protection being afforded the foliage could be detected after an exposure beyond 5 days. In the 6–8 day column, in which it is indicated that 100 per cent of the insects were dead or moribund, as much of the foliage was consumed as on the check plants. However, at the end of 20 days no toxicity was evident.

In table 1, showing the results in bean plants treated with 0.018 per cent rotenone spray, it is evident that the original toxicity is not so great as when a dust containing 0.75 per cent rotenone is used. It is also evident that the toxicity is lost more rapidly, regardless of the exposure given. There is evidence of toxicity through the 6–8 day period in both mortality and the amount of plant tissues consumed. Beyond this period there is no evidence of plant protection remaining.

In all the shaded tests, the plants were afforded good protection from insect injury for a period of two weeks. It will be noted that the mortality was high throughout this period also. Under shade conditions the plants did not hold up for further tests.

On three occasions, eggs were deposited on shade test plants in the first three days that the plants were on test. One egg mass containing 31 eggs did not hatch. Another containing 54 eggs hatched and all the larvae died without showing evidence of having fed. The third contained 43 eggs which hatched. These larvae left some feeding injury but all died in the first instar.

Table 1.—Mortality[1] of Mexican bean beetle on bean plants treated with derris.

Exposure	Condition	Days Elapsed Between Treatment and Starting Tests					
		None	3–5	6–8	9–11	12–14	20
	Dust, 0.75 Per Cent Rotenone						
Sun	Dead, per cent		12	4	4	16	0
	Moribund, per cent		69	96	8	8	0
	Total dead and moribund, per cent		81	100	12	24	0
Shade	Dead, per cent	66	52	27	39	22	
	Moribund, per cent	29	45	69	53	63	
	Total dead and moribund, per cent	95	97	96	92	85	
	Spray, 0.018 Per Cent Rotenone						
Sun	Dead, per cent		8	0	0		
	Moribund, per cent		32	28	0		
	Total dead and moribund, per cent		40	28	0		
Shade	Dead, per cent	25	13	12	18	0	
	Moribund, per cent	61	73	76	50	68	
	Total dead and moribund, per cent	86	86	88	68	68	

[1] The number of tests for each period and exposure ranged from 1 to 12. Twenty-five insects were used in each individual test. Counts were made three days after beetles were placed on plants. Comparative tests on sun and shade plants were made at the same time on samples from the same collection of insects.

SUMMARY.—From the data presented it appears that derris on bean foliage under field conditions did not afford protection against the Mexican bean beetle beyond seven days of exposure.

On shaded bean plants protected from the weather, derris was very effective over a period of two weeks or as long as the plants held up.—1-7-38.

LITERATURE CITED

Jones, H. A., W. A. Gersdorff, E. L. Gooden, F. L. Campbell and W. N. Sullivan. 1933. Loss in toxicity of deposits of rotenone and related materials exposed to light. JOUR. ECON. ENT. **26**(2):451–70. Illus.

New Facts Concerning Cryolite Spray Residues

S. Marcovitch and W. W. Stanley,* *Tennessee Agricultural Experiment Station, Knoxville*

In 1791, an epidemic of yellow fever occurred in the city of Philadelphia. The scope of knowledge was so restricted that people were afraid to walk the streets. The dismay and affright reached such proportions that people would not shake hands with their friends, fearing the contagion of yellow fever. Dissemination by the mosquito was not thought of at that time. In the fourteenth century 25,000,000 people died as a result of the black death, or bubonic plague. The people feared to drink from wells because the available evidence, if such it can be called, indicated that the wells were being poisoned. The role of the flea in the dissemination of the plague was not known until recent times.

A similar fear complex, shrouded in ignorance, prevails at the present time in regard to the spray residue situation. Slight fevers or stomach upsets, when the cause is not discernible, are often erroneously attributed to the consumption of sprayed fruit. Again the wells are poisoned. This time the fear disseminated is of mottled enamel on teeth, and the suspicion is spreading from wells of fluorine-bearing waters to apples containing fluorine spray residues.

We do not know the cause of these prevailing stomach upsets, but we have attempted to gather all the facts and scientific data possible on cryolite spray residues. It must be determined whether or not the orchardists and the apple industry are being dealt with unfairly. Only the more salient points of the subject will be discussed at this time.

Mottled Enamel—A Water-Borne Disease.—The arsenical residue scare had its origin in Manchester, England, where, in 1900, 70 deaths resulted from the drinking of beer contaminated with soluble arsenious acid ranging from one-fourth grain to 3 grains of As_2O_3 per gallon. The Royal Commission, appointed to study the outbreak, recommended that a tolerance of .001 grain of arsenic per pound of liquid or .01 grain per gallon of beer or per pound of foodstuffs be enforced. This English tolerance on soluble arsenious acid is the basis of the American tolerance on the relatively insoluble lead arsenate. These two materials are not similar, for arsenious acid has an M.L.D. of 5 milligrams per kilogram, and lead arsenate 500 milligrams per kilogram of body weight.

In 1932, one part or more per million of dissolved fluorine in the drinking water of Arizona wells was found to be the cause of mottled enamel of teeth. Since fluorine is also the activice principle in cryolite, the same tolerance, .01 grain of fluorine per pound of foodstuffs, was decreed.

A few years ago the fear centered around arsenic, but now there is more concern regarding the lead in lead arsenate, since about 1 part of lead in 10,000,000 parts of drinking water passing through lead pipes has been found to cause lead poisoning.

A perusal of these cases reveals a characteristic that is common to all three materials; namely, that the chemical is in *solution* in a liquid medium (beer or drinking water). This is not a characteristic of spray residues. Mottled enamel is now classed as a water-borne disease by Dean & Elvove (1936) of the Public Health Service, in the following words: "In the light of present knowledge, mottled enamel is a water-borne disease associated with the ingestion of toxic amounts of fluoride present in the water used for drinking and cooking during the period of tooth calcification."

In our study we have attempted to determine the toxicity of fluorine in solution when used for drinking and cooking as contrasted with fluorine as cryolite in the diet.

Mottled enamel is most prevalent and severe where well water is used in the arid states of the Southwest, notably in Texas, western Kansas and Arizona. Outside of the United States, important endemic areas occur in Argentina, North Africa and Italy. It is important to note that the localities in which mottled enamel is endemic are either volcanic or regions that are hot and dry. Warm climates necessitate the intake of large quantities of water for effective dissipation of heat. The fluid intake in India is commonly as much as

* In cooperation with the Departments of Chemistry and Home Economics.

13 liters each day (Hunt 1912). Actual records of water consumption by children in Arizona show that from 3 to 4 pints were ingested during the summer months. In hot days this amount was increased to 5 pints. Adults working in fields consumed 1½ to 2 gallons of water.

Water engineers generally estimate a greater allowance for water consumed in cooking than in drinking. The recipe for rice calls for 3½ cups of water to one-half cup of rice. Some of the less tender meats require from 3 to 5 hours of simmering and boiling to make them edible. Even bread requires almost half its weight in water to prepare it for baking. In many homes it is the custom to have a teakettle of water simmering on the stove in order to provide a ready supply of hot water. In the course of time the salts in the water precipitate out to such an extent as to necessitate frequent removal of the scale to prevent clogging of the neck. We obtained a sample of such scale from a district in Arizona where fluorine was present in the drinking water to the extent of 8.1 p.p.m. This scale analyzed 8,072 p.p.m. of fluorine and serves to emphasize the fact that fluorine may become many times more concentrated than it was in the original water. When fed to rats at the rate of 15 p.p.m. of fluorine, this scale produced definite striations on the teeth.

Toxicity tests with albino rats showed that 4 p.p.m. of fluorine as sodium fluoride in the drinking water is capable of producing striations on the teeth in 50 per cent of the animals. With cryolite, the first indication of faint striations were produced at 11 p.p.m. of fluorine. On a cooked diet (1700 cc. of water used to prepare 500 g. of beans or rice) definite striations were produced with 1 to 2 p.p.m. of fluorine in the water supply. These latter levels closely approximate those found to affect human beings.

THE FACTOR OF SAFETY FOR CRYOLITE.—A material that is incapable of causing fatalities satisfies one of the essential requirements of the ideal insecticide. With some of our present stomach poisons, such as the arsenicals, fatalities often result when they are accidentally swallowed by man or animals. To date, we have been unable to kill animals with cryolite, even in a dose as high as 13,500 milligrams per kilogram of body weight. This is equivalent to 1½ pounds for an adult human being. For insects, however, cryolite has an M.L.D. of .05–.07 milligram per gram of insect, which is similar to that of lead arsenate (Shepard & Carter 1933). Since no fatalities have ever been recorded with cryolite, we may say that cryolite has a high factor of safety for mammals.

THE NATURAL DISTRIBUTION OF FLUORINE IN FOODS AND BEVERAGES.—All foods examined contain fluorine, but marine foods and those prepared with bone meal are especially rich in this element. Salmon and sardines were found to contain up to 7.3 p.p.m. A prepared baby food with 2 per cent bone meal was found to analyze 12 p.p.m. of fluorine. Tea contained up to 80 p.p.m., and a phosphate baking powder, 228 p.p.m. An exclusive diet, before the eighth year, of biscuits made with such baking powder might produce mottled enamel; but such a condition would not occur in practice.

PUBLIC HEALTH SIGNIFICANCE OF CRYOLITE RESIDUES.—In the case of the investigation in regard to benzoic acid, the Referee Board, with Ira Remsen (1909) as chairman, used 300 grams of benzoated food per day for each subject, or about 20 per cent of the diet. In actual practice, sprayed food would constitute less than 10 per cent of the diet. Records show that the average person consumes about 4 pounds of water per day during the summer months, with an additional 4 to 6 pounds required for cooking. Therefore, since the average diet weighs about 2½ pounds, the water consumption is more than 30 times as great as the possible consumption of sprayed food.

We have shown that 4 p.p.m. of fluorine as cryolite in the total diet will not produce striations. Even if we assume that 20 per cent of the diet is sprayed, we arrive at the figures of 5 times 4, or 20 p.p.m., which would not be injurious to health. Such quantities are not likely to occur under practical conditions. Oranges contain .2 p.p.m. of fluorine. One lot of oranges, when small, dusted with cryolite showed upon analysis no detectable amounts of added fluorine in the juice or rind. To prohibit the use of cryolite on oranges because of imaginary danger is absurd.

CONCLUSION.—In 1933, the Secretary of Agriculture announced the tolerance on

fluorine in the following statement: "The scope of knowledge of the toxicity of fluorine is restricted. Available scientific data indicate that it is not more toxic than arsenic." It is quite evident that there was not enough information available at that time to furnish an adequate answer to the question: Do fruits and vegetables which have been sprayed with cryolite contain any added poisonous or deleterious ingredient which may render such foods injurious to health?

Such information as was definitely available did not pertain to foods, but dealt with the toxicity of fluorine in water supplies used for both drinking and cooking. When 1 part per 1,000,000 of fluorine was found in the water, mottled enamel showed an incidence of 10 per cent. Our work shows clearly and definitely that 1 part per 1,000,000 in a water supply is of a totally different quality and quantity from 1 part per 1,000,000 as spray residue. Chemicals in solution are known to be more readily absorbed and therefore more toxic. The toxicity of the soluble barium chloride, for example, is well known; the relatively insoluble barium sulfate is nontoxic. These differences are also recognized in the British tolerance, where .001 grain of arsenic per pound of liquid is allowed to .01 of a grain per pound of solids. Such a recognition for fluorine would raise the tolerance to .1 grain at once. In this connection it is of interest to note that cryolite is ordinarily incapable of causing fatalities to human beings and has therefore a high factor of safety for mammals as compared with soluble fluorides or arsenicals.

In addition, if we calculate the amount of water ingested by drinking and that required for cooking, we arrive at 8 to 10 pounds per person daily. Assuming that 10 per cent of our food may be sprayed, the consumption of water is more than 30 times as great as that of sprayed food. The present tolerance for fluorine is a standard for water supplies that has no application to cryolite spray residues.

The normal distribution of fluorine in our food in many instances is far above the present tolerance of 1.4 p.p.m. Marine foods, such as salmon and sardines, contain up to 7.3 p.p.m. of fluorine. Yet mottled enamel has been produced by no other means in the United States than the continued ingestion of water containing toxic amounts of dissolved fluorides during the period of calcification (between birth and 8 years of age) of the crowns of the permanent teeth. Mottled enamel is, therefore, a water-borne disease.

Our data lead to the conclusion that in cryolite we have a material that is reasonably safe to human health, an effective insecticide, harmless to foliage, and economical in price.—1-7-38.

LITERATURE CITED

Dean, H. T., and E. Elvove. 1936. Some epidemiological aspects of chronic dental fluorosis. Amer. Jour. Pub. Health **26**: 567.

Hunt, E. H. 1912. The regulation of body temperature in extremes of dry heat. Jour. of Hyg. **12**: 479.

Remsen, Ira. 1909. The influence of sodium benzoate on the nutrition and health of man. U.S.D.A Rept. **88**.

Report of the Royal Commission. 1900. Appointed to inquire into arsenical poisoning. London.

Shepard, H. H., and R. H. Carter. 1933. The relative toxicity of some fluorine compounds as stomach insecticides. JOUR. ECON. ENT. **26**(4):913. Aug.

Soybean Flour as a Spray Material

M. D. FARRAR, *Illinois Natural History Survey, Urbana,* and W. P. FLINT, *Illinois Natural History Survey and Illinois Agricultural Experiment Station, Urbana*

Soybean flour is made by grinding soybean cake after the oil has been removed by any one of several processes. The flour, as sold in trade, contains 6.18 to 8.88 per cent of fat when manufactured from expeller-process cake and 1.58 per cent of fat from solvent-process cake (Bailey 1935), a high per cent of water-dispersable protein matter and some solids. The usefulness of soybean flour in agricultural sprays depends on the water-dispersable colloids. These give to a spray mixture certain spreading and sticking properties.

Table 1 gives the average composition (LeClerc & Bailey 1936) of the three kinds of soybean flours. The products that probably play a part in mixtures of soybean flour and spray materials are protein, sugars, ash and lecithin. These total 66 per cent of expeller-process flour.

Table 1.—The composition* of average soybean flours of the three types.

PRODUCTS	WHOLE BEAN	EXPELLER	SOLVENT
Moisture	7.00	7.70	7.00
Fat	21.10	7.30	2.00
Fiber	2.30	3.00	2.80
Protein	41.60	47.50	54.00
Sugars (mostly sucrose)	9.30	11.40	12.00
Other carbohydrates	14.10	17.30	16.50
Ash	4.60	5.80	5.70
Lime (CaO)	0.28	0.35	0.37
Phosphoric acid (P_2O_5)	1.21	1.40	1.54
Lecithin	1.10	1.30	
Alkalinity of ash	24.10	27.90	
Urease activity	2.50	2.40	

* Composition is expressed as per cent, except alkalinity of ash and urease activity, of which the index number is given.

IN ORCHARD SPRAYS.—Experiments started in 1934, in which soybean flour was used as a spreader for sprays, have been continued to date. A large number of laboratory and field experiments have been made to determine the effect of adding the flour to many types of spray mixtures. Its chemically inactive property makes it compatible with practically all agricultural sprays. The water-dispersable colloids are only mildly affected by water hardness. Actually, however, under field conditions less flour is required with soft than with hard water to give equivalent degrees of dispersion to a spray mixture.

The outstanding property of soybean flour in sprays is the resulting deposition of a smooth, even spray deposit. When this property is combined with that of sticking, for example, when used with soybean oil, a residue can be deposited superior in amount and coverage to that obtained with any other spreader tested.

SMALL AMOUNTS BEST.—Experiments indicate that, to deposit a very uniform film, one to two pounds of soybean flour are required in a standard codling moth spray containing lead arsenate. In obtaining such a deposit there is an excess of run-off, resulting in inferior control of codling moth. Experiments demonstrate that soybean flour used at 1 or more pounds per 100 gallons with sprays of lead arsenate, calcium arsenate or synthetic cryolite are not so efficient in killing young codling moth larvae as are the same sprays without the flour. This is borne out in both laboratory and field experiments over a three-year period.

When the amount of soybean flour is reduced below 1 pound per 100 gallons, the efficiency is increased over that of the spray in which flour is not used. Very limited data seem to indicate that under most conditions one-fourth pound of soybean flour per 100 gallons is about right to produce maximum efficiency. L. F. Steiner (unpublished laboratory data for 1937) reports one-fourth pound soybean flour to be equivalent in deposit-building properties to one-fourth pound dry soap.

In table 2 are given codling moth data which indicate the effects of certain properties of the soybean flour in building spray residues under field conditions. Compare items 1 with 2, and 3 with 4 for lead residues.

Soybean flour at 1 pound per 100 gallons of spray material is not equivalent to one-half per cent mineral oil in building deposits. Washing experiments, however, indicate that residues containing soybean flour are easier to remove than similar residues with mineral oil.

USED AS OIL EMULSIFIER.—The property of soybean flour to emulsify mineral oils may be useful in making quick-breaking emulsions or emulsifying other products in the spray tank. Certain of these properties are mentioned by Farrar & Flint (1936).

It appears to the writers that soybean flour has a definite place in controlling codling moth when a relatively heavy program must be maintained. It has value both as a sticker and spreader that may be used with many spray mixtures.

As a cheap and efficient deposit-builder for lead arsenate it can be used in those sprays applied between the last fungicide and the first oil sprays to prolong this interval, thereby reducing injury caused by mineral oils when applied too close to the last sulfur spray. Two weeks is the minimum interval; the interval required is longer in dry weather.

The chemically stable properties of soybean flour permit its use with a wide range of insecticides or fungicides. When used in a spray mixture it exhibits a pro-

nounced spreading action with a moderate degree of adhesion.

USED FOR MAKING DUSTING SULFURS WETTABLE.—There has been a demand from the growers of apples and peaches for a method of making wettable ground sulfurs. The mixing of 5 pounds of soybean flour with 95 pounds of dusting sulfur is a simple answer to this problem. The two materials are easily mixed in any equipment that will thoroughly mix other dry materials.

The mixture of soy flour and sulfur may be stored until required for use. In the mixing of sulfur for the spray tank, a definite procedure should be followed. The required amount of sulfur-flour mixture should be placed in a bucket and enough water added to wet the sulfur to the consistency of a thick paste. (The use of too much water before a paste is formed or the dumping of the dry mixture directly into the tank will cause some of the sulfur to "ball" and become difficult to wet.) As soon as a paste is formed, additional water may be added and the whole dumped into the spray tank. The cheaper non-wettable sulfurs handled in this manner produce a spray of easily-suspended sulfur particles.

The fungicidal action of this mixture will be in keeping with commercial wettable sulfurs that have a comparable sulfur-particle size and sulfur content. The material should be useful in the scab and brown rot sprays on peaches, and on apples when a ground wettable sulfur might be used.

Following the mention at fruit growers' meetings of the results of our work with this material in 1935, the commercial use of soybean flour in orchard insect control has been surprisingly large. Experiment stations from both coasts report it useful as a sticker or spreader. Growers throughout Illinois have found the flour easy to handle and very adaptable in their spray programs. Figures from a single manufacturer list 60 tons of soybean flour marketed for spray purposes during 1937. Probably 100 tons were used in sprays last year.—1-7-38.

Table 2.—Field experiment on Red Delicious, southern Illinois, 1937, in which soybean flour was used as sticker and spreader.

ITEM[1]	COVER SPRAYS[2]			CODLING MOTH		RESIDUE
	Second	Third and Fourth	Fifth, Sixth, Seventh and Eighth	Per Cent Stings	Per Cent Entries	Grains of Lead Per Pound of Fruit at Harvest
1	Lead arsenate, 4 lbs. Lime, 4 lbs. Soy flour, 1 lb.	Lead arsenate, 4 lbs. Lime, 4 lbs. Soy flour, 1 lb.	Lead arsenate, 4 lbs. Lime, 4 lbs. Soy flour, 1 lb.	18.3	1.8	.180
2	Lead arsenate, 4 lbs. Lime, 4 lbs. Soy flour, 1 lb.	Lead arsenate, 4 lbs. Lime, 4 lbs. Mineral oil, ½%	Lead arsenate, 4 lbs. Lime, 4 lbs. Mineral oil, ½%	13.1	3.0	.230
3	Lead arsenate, 4 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb. Soy flour, 1 lb.	Lead arsenate, 4 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb. Soy flour, 1 lb. Mineral oil, ½%	Lead arsenate, 3 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb. Soy flour, 1 lb.	15.2	2.5	.241
4	Lead arsenate, 4 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb. Soy flour, 1 lb.	Lead arsenate, 4 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb. Soy flour, 1 lb. Mineral oil, ½%	Lead arsenate, 3 lbs. Lime, 1.5 lbs. $CuSO_4$, .75 lb.	15.8	1.3	.208

[1] The term *item* refers to one or more plots, all plots in an item receiving the same treatment.
[2] In all plots, the calyx spray consisted of 3 pounds lead arsenate, 3 pounds lime; the first cover spray consisted of 4 pounds lead arsenate, 4 pounds lime. All materials except mineral oil were used on the basis of pounds per 100 gallons of spray.

LITERATURE CITED

Bailey, L. H., R. G. Capen and J. A. LeClerc. 1935. The composition and characteristics of soybeans, soybean flour and soybean bread. Cereal Chem. 12(5):451.

LeClerc, J. A., and L. H. Bailey. 1936. Soya flour. U.S.D.A., Bur. Chem. and Soils, Food Res. Div. Contrib. 303.

Farrar, M. D., and W. P. Flint. 1936. Injection method for dispersion of oil into tank mixtures. JOUR. ECON. ENT. 29(1):216.

Potato Spraying Experiments in North Dakota*

J. A. MUNRO and LOUIS A. SCHIFINO, *North Dakota Agricultural Experiment Station, Fargo*

The increasing demand in many sections of the country for potatoes grown in North Dakota for seed purposes has stimulated interest in spraying procedures for the protection of the crop. While spraying for control of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is general in North Dakota, spraying for the control of other potato insects is less common. Insecticides containing copper are not widely used. The present study, of which this paper is a preliminary report, is directed toward the formulation of a satisfactory and efficient spraying program for potatoes.

GENERAL PLAN OF THE EXPERIMENT.—A field planted to Irish cobbler potatoes was divided into strip-row plots with each plot four rows in width running the entire length of the field. The plots were arranged in accordance with the half-drill strip method as described by Blodgett & Mader (1935), giving four comparisons for the checks and the treatments. The treatments were (1) Bordeaux mixture and calcium arsenate, (2) Bordeaux mixture and (3) Bordeaux mixture and barium fluosilicate.

TREATMENT OF PLOTS.—The Bordeaux spray used in the experiments consisted of 6 pounds of copper sulfate (blue vitriol) to 3 pounds of high calcium hydrated lime in 50 gallons of water. Calcium arsenate and barium fluosilicate (*Dutox*) were added to the Bordeaux mixture at the rate of 2 pounds to 50 gallons of spray.

The applications were made with a horse-drawn traction sprayer equipped with a four-row boom having three nozzles to the row, delivering 100 to 125 pounds of pressure and distributing approximately 85 gallons of spray per acre. Each treated plot received four applications; the first application was applied July 17 and the process repeated at intervals of 10 to 14 days. To eliminate differences in yields due to feeding of the Colorado potato beetle, all plants, including the checks, were sprayed once with calcium arsenate.

METHOD OF TAKING DATA.—In taking the record of the effectiveness of each treatment, counts were made of the potato leafhopper nymphs and potato flea beetle punctures. Counts were made on each treatment in parallel strips across the plots to permit statistical comparisons. Leaf-hopper nymphs were counted on the main leaves of the main stem of the plant. This method was used in preference to the entire plant method because in previous experiences it had been found to be faster and more nearly accurate. Population counts were made on the second day after each application of the treatment; the number of live nymphs remaining on the leaves of the main stems of 10 plants in each of the treatments was recorded.

Flea beetle punctures were counted on the trifoliate leaves at the fourth node, the eighth node and the top of the potato plant. The number of punctures per trifoliate leaf was counted with the aid of a binocular microscope. Such counts were made on five plants in each treatment, three times during the season.

In addition to the above counts, the relative number of adult leaf-hoppers and flea beetles present at certain times during the season was estimated by counting the number captured with twenty sweeps of a small hand net while walking along the potato rows.

Tuber yields were taken on single rows of sufficient length to constitute an area of .01 acre. A rectangular area was marked off across all the plots of suffi-

* The investigation reported in this paper is in connection with a project of the North Dakota Agricultural Experiment Station and is published by permission of the Director.

cient length for the individual rows to comprise .01 acre in area. The plots were then dug with a potato digger and the potatoes from each row were weighed separately. Since the rows were 37 inches apart, the wheel injury was probably slight but doubtless affected all rows the same.

The data obtained, except insect counts in table 1, were treated by the variance method of statistical analysis (Snedecor 1934).

Table 1.—Average number of insects per sweep in plots treated during potato spraying experiments.

Insects	Check	Bordeaux and Calcium Arsenate	Bordeaux Alone	Bordeaux and Barium Fluosilicate
Flea beetles	7.32	5.43	5.60	5.50
Leafhoppers	1.86	1.13	1.03	1.08

PREVALENCE OF INSECTS AND DISEASE.—Potato flea beetles, *Epitrix cucumeris* Harr., were more numerous than any other destructive insect, as shown in table 1. The first brood of flea beetles was noticed July 19. They were present for the remainder of the season. Both adults and nymphs of the potato leafhopper, *Empoasca fabae* Harr., were present from July 1 to the end of the season. The infestation of leafhoppers was light and caused no appreciable injury during the fore part of the season (table 1). With the advance of the growing season, the amount of tipburn increased, possibly due to the potato leafhopper or perhaps to a combination of physiological factors. Aphids were present during the first week of July but later were entirely absent. Colorado potato beetles, present in the early part of the season, were controlled by one application of calcium arsenate. Traces of early blight caused by *Alternaria solani* (Ell. and Mort.) were found, but there was never enough to cause any appreciable injury. Late blight caused by *Phytophthora infestans* (Mort.) D. was entirely absent.

DISCUSSION OF THE RESULTS—A comparison of yields in table 2 indicates that all of the treated plots gave increased yields over the check which are statistically highly significant. The largest increase in yield was obtained by spraying the potato plants with Bordeaux mixture and calcium arsenate, while the smallest gain was obtained by spraying with Bordeaux mixture and barium fluosilicate. These results are in general agreement with those of Wolfenbarger (1934) in similar work conducted on muckland potatoes in western New York. The smallest gain in yield, obtained by spraying with Bordeaux mixture and barium fluosilicate, may perhaps be attributed to possible injury from the barium fluosilicate in the spray as suggested by Anderson & Walker (1937).

Table 2.—Average number of leafhopper nymphs per main stem of potato plant, average number of flea beetle holes per trifoliate leaf and average yield of potatoes per acre for the treatments in potato spraying experiments.

Treatment	Leafhoppers	Flea Beetle Holes	Yield in Bushels Per Acre
Check	3.19	95.42	149.69
Bordeaux mixture and barium fluosilicate	1.57	71.04	177.08
Bordeaux mixture	1.38	82.42	181.36
Bordeaux mixture and calcium arsenate	1.51	60.86	191.29
Significant differences between means, odds 21:1	1.07	9.00	10.46

Menusan (1937) has shown that in the absence of potato leafhoppers. Bordeaux spray applied to the foliage failed to give increases in yield; however, when leafhoppers were present the application of Bordeaux spray resulted in increased yields attributed to leafhopper control. There is a lack of numerical data to substantiate the conjecture that increased insect control will always be associated with increased yields (MacLeod and Maughan 1937). Tables 1 and 2 show that the infestation of leafhoppers throughout the season is very light. There would be grave danger to surmise that a

Table 3.—Average gain in bushels per acre and average reduction of flea beetle holes per trifoliate leaf (figures in parentheses) of treatment at side of table over treatment at the top of the table for the experiment in table 2.

TREATMENT	CHECK	BORDEAUX AND BARIUM FLUSILICATE	BORDEAUX
Bordeaux and barium fluosilicate	27.39 (24.38)		
Bordeaux	31.67 (13.00)	4.28 (+11.38)	
Bordeaux and calcium arsenate	41.60 (34.56)	14.21 (10.18)	9.93 (21.56)

Significant difference: Yield 10.46; flea beetle holes, 9.00

control of less than two leafhopper nymphs per main stem of the potato plant can result in such highly significant increases in yield.

One might assume that the increases in yield are due to the reduction of flea beetle injury. This is not entirely true since the fluctuations in increased yields cannot be explained by the comparable reduction of flea beetle holes, as shown in table 3. Perhaps some of the gains due to spraying may be attributed to the effect which copper in the form of Bordeaux mixture exerts on the potato plant (Blodgett & Mader 1935).

The variation in the differences of yields and insect control of the treated plots among themselves suggests that some other factor, or group of factors, at present unaccounted for, enters into the problem. Many seasons of work under a variety of conditions will be required to clarify these points.—1-7-38.

LITERATURE CITED

Anderson, L. D., and H. G. Walker. 1937. Control of the potato flea beetle, *Epitrix cucumeris* Harr., on the eastern shore of Virginia. Amer. Potato Jour. **14**(10):319–25. Oct.

Blodgett, F. M., and E. O. Mader. 1935. Effects of modification of the potato-spray program. Cornell Univ. Ag. Exp. Sta. Bul. **621**: 1–34.

MacLeod, G. F., and F. B. Maughan. 1935. Some factors involved in measuring results of experiments with onion thrips. JOUR. ECON. ENT. **28**(1):150–3. Feb.

Menusan, Jr., Henry. 1937. Leaf-hopper injury to potato foliage and its relation to tuber yields. JOUR. ECON. ENT. **30**(5):772–7. Oct.

Snedecor, George W. 1934. Calculation and interpretation of analysis of variance and covariance. Collegiate Press, Inc., Ames, Iowa. 96 pp.

Wolfenbarger, D. O. 1934. Some effects on potato flea beetle, *Epitrix cucumeris* Harr., injury and yields by spraying. JOUR. ECON. ENT. **27**(1):118–20. Feb.

Preliminary Studies of Wireworms Affecting Potato Tubers in North Dakota[1]

J. A. MUNRO and LOUIS A. SCHIFINO, *North Dakota Agricultural Experiment Station, Fargo*

Information obtained from a survey questionnaire[2] on wireworm injury revealed that 58 per cent of the potato growers in North Dakota suffered losses from these insects in 1937. Since the wireworm problem is of grave concern to the potato growers, a series of experiments was designed to study this problem. Some of the information obtained this season is presented in this paper.

SURVEY OF WIREWORM INJURY.—Potatoes are subject to injury by wireworms from the time the seed is planted until the potatoes are harvested in the fall. Seed pieces are often severely injured by the tunneling of wireworms; however, most of the injury occurs on the developing tubers. Early in the season, the larvae feed on the developing tubers and leave deep, funnel-shaped or large shallow cavities in the mature tubers, and often they cause the tubers to be misshapen. Late season injury by wireworms is characterized by numerous well-defined pits, deep holes and tunnels. Late wireworm injury is the most common and of greatest concern to the potato growers in North Dakota. In some instances the

[1] The investigation reported in this paper is in connection with a project of the North Dakota Agricultural Experiment Station and is published by permission of the Director.

[2] Conducted in cooperation with the State Extension Service and the State Seed Department.

injury is so severe that the crop cannot be profitably harvested.

During the months of September and October, a survey of the amount and distribution of wireworm injury was conducted in five counties in the Red River Valley. Five thousand tubers from 50 farms were examined. One hundred tubers were selected in the field at random and the injuries recorded. A complete record of soil type, crop rotation systems and other additional information was obtained. The survey showed that 14.8 per cent of the potato tubers was injured by wireworms.

RELATIVE IMPORTANCE OF WIREWORM SPECIES.—Some work was carried on to determine the relative importance of the wireworm species involved in tuber injury. After the potato vines had died, several fields were visited and examined in detail. The potato hills were dug and the soil removed and sifted through three screens (4, 12 and 16 mesh to the inch). All the wireworms thus found were recorded as to species and number. The tubers were examined and the number of injured tubers was listed. These findings are shown in table 1.

Only the potato hills that harbored wireworms were included in the counts; potato hills in which no wireworms were found, even if injury was present, were discarded.

Since it was found that *Corymbites aeripennis destructor* Brown was the most prevalent species, additional field work was carried on to determine the fall population of this species in relation to tuber injury.

Seventy potato hills selected at random were examined in fields which were representative of the potato producing area where wireworms have been a major source of loss to the growers. These results are listed in table 2.

Table 1.—Wireworm injury to potato tubers.

SPECIES*	NUMBER OF HILLS IN WHICH FOUND	AVERAGE NUMBER OF TUBERS PER HILL	AVERAGE NUMBER OF INJURED TUBERS PER HILL	AVERAGE NUMBER OF WIREWORMS PER HILL
Corymbites aeripennis destructor Brown	41	4.85	2.56	4.05
Melanotus spp.	8	4.125	.50	1.63
Hemicrepidius spp.	3	5.00	0.00	1.33
Limonius (*Pheletes*) spp.	1	4.00	1.00	1.00

* Identifications by Dr. A. G. Boving.

Table 2.—*Corymbites aeripennis destructor* Brown in relation to tuber injury.

Average number of tubers per hill	4.58
Average number of injured tubers per hill	1.56
Average number of wireworm holes per hill	4.48
Average number of wireworms per hill	1.22

It will be noticed that in table 1 only the potato hills that harbored wireworms were included in the counts, while in table 2 all of the hills that were dug, regardless of number of wireworms and injury, were recorded.

Corymbites aeripennis destructor Brown is the most abundant species and of greatest concern in this vicinity. *Melanotus* spp., *Hemicrepidius* spp. and *Limonius* (*Pheletes*) spp. were also found but are perhaps of no economic importance since they were never numerous and were frequently found in potato hills where the tubers were not injured.—1-7-38.

A CONFERENCE of district supervisors and others engaged in the enforcement of foreign plant quarantines was held in Washington, D. C., June 13 to 17, inclusive. Those in attendance at the conference were the following: A. G. Webb, and L. M. Scott, Seattle, Wash.; C. E. Cooley, San Francisco, Calif.; C. E. Bellis, Nogales, Ariz.; T. A. Arnold, El Paso, Tex.; J. B. R. Leary, Laredo, Tex.; O. D. Deputy, Brownsville, Tex.; W. T. Dillard, New Orleans, La.; Geraldus Gay, Norfolk, Va.; W. A. Ranck and Richard Faxon, Baltimore, Md.; R. D. Kennedy, Philadelphia, Pa.; Max Kisliuk, Jr., New York; W. H. Freeman, Boston, Mass.; and W. W. Wood, Detroit, Mich.

Control of Onion Thrips

NEELY TURNER and G. L. WALKER, *Connecticut Agricultural Experiment Station, New Haven*

The onion thrips, *Thrips tabaci* Lind., has been a major pest of onions for many years. Horsfall & Fenton (1922) and Bourne (1926) have made studies of its life history and investigations of sources of infestation. The treatment usually recommended has included frequent applications of nicotine sulfate and soap. However, Horsfall & Fenton (1922) called attention to the fact that dry hot weather was very favorable to development of thrips, and that under such conditions spraying with nicotine would not save the crop. Tate & Andre (1936) published results of laboratory studies which indicate that the amount of nicotine usually recommended for onion thrips is inadequate. Maughan (1934) proposed the use of crude naphthalene dusted on the plants and showed that this treatment is effective.

This paper includes results of field tests conducted by the Connecticut Agricultural Experiment Station during the years 1933 to 1937. In 1937 the work was carried out in cooperation with the Crop Protection Institute project on *Ultrawet*. In all spray tests the materials were applied by a garden tractor with a spraying attachment. This sprayer held 20 gallons of material, developed 150 pounds pressure and had a capacity sufficient to supply six nozzles for three rows. In the dusting experiments, hand-operated, bellows-type knapsack dusters were used. These tests were made in commercial onion fields, and except where noted the onions were grown from sets. Usually, because of early maturity these onions were infested less heavily than onions grown from seed.

TESTS IN 1933.—Nicotine sulfate (40 per cent) at a dilution of 1 to 800, a pyrethrum spray (*Evergreen*) and an extracted rotenone spray (*Insect-Nox*), each used at the manufacturer's dilutions, were applied twice during 1933. In all cases, .5 per cent soap (by dry weight) was added in the form of a 40 per cent solution of a potash-cocoanut oil soap. All materials reduced the number of thrips, and nicotine sulfate was slightly more effective than the other materials. Sprays were applied on June 9 and June 20, and as late as July 6 there was a marked difference in appearance between sprayed and unsprayed plots. However, there were no differences in yield of the plots. The number of thrips per plant (20) was probably too low to affect the yield on the untreated plots.

In the same year, the nicotine sulfate-soap spray was applied to another small field of onions on June 2, 9, 19 and 28. Counts made before and after spraying showed that the treatment reduced the number of thrips sometimes as much as 90 per cent, but that the population increased rapidly after spraying. As soon as the onion tops fell over, spraying was impossible and the plots became heavily infested.

TESTS IN 1934.—The mixture of 40 pounds crude naphthalene and 60 pounds hydrated lime suggested by Maughan (1934) was applied to set onions on July 4, 11 and 18, and to seed onions on July 4, 11, 18 and 27. The comparatively late dates of application were due to abundant rainfall during June which kept the thrips population low. The dusts at no time reduced the number of thrips by more than 50 per cent. Moreover, the dusted onions were injured by the applications. It is possible that the naphthalene failed to control thrips in this field because of wind movement.

TESTS IN 1936.—Cubé, cubé-sulfur and sulfur dusts were tested in small plots of seed onions. The rotenone content of the cubé dusts was .75 per cent and the cubé-sulfur dust contained 73 per cent sulfur. The thrips infestation was light, and applications were made on July 25, August 7 and August 17. There was no satisfactory control of thrips, and sulfur caused some injury to the onion tops.

TESTS IN 1937.—Onion thrips appeared in large numbers late in May and by the middle of June had damaged set onions. Three series of tests were made, and the results recorded in terms of reduction in number of thrips. The plots were laid out in strips across the field, at least 9 rows not less than 200 feet long. Twenty-five plants of approximately the same size were taken at random in each plot for a count of the number of thrips. The leaves were torn from the plants, and the num-

ber of thrips counted as accurately as possible.

Overhead irrigation was available in all fields and was used by the grower during the periods of dry weather. This kept the onions in good condition but apparently did not affect the thrips in the least.

The materials used in the three series of tests were as follows (all amounts for 50 gallons of water):

(1) Pure ground cubé root (4 per cent rotenone), 2 pounds;

(2) Same as 1 plus *Ultrawet*, 1–800;

(3) Same as 1 plus *Ultrawet*, 1–1600;

(4) Same as 1 plus *Aresket*, 1–1600;

(5) Same as 1 plus sulfur, 4 pounds, mixed with *Ultrawet*, 1–1600;

(6) Sulfur, 4 pounds, mixed with *Ultrawet*, 1–1600;

(7) Nicotine sulfate (40 per cent), 1–800, plus *Ultrawet*, 1–1200;

(8) Nicotine sulfate (40 per cent), 1–800, plus *Aresket*, 1–1600.

The first series of tests was made on set onions having an average of 95 thrips per plant before spraying. Sprays were applied on June 16 and 25 and July 1. The counts refer to nymphs only, and the results are given in table 1.

Table 1.—Average number thrips per plant after spraying on June 16, 25 and July 1.

TREATMENT	JUNE 18	JUNE 29	JULY 6
Cubé	55.4	60.8	57.8
Cubé-*Ultrawet*, 1–800	35.7	38.3	43.7
Check	102.6	117.7	162.2
Cubé-*Ultrawet*, 1–1600	28.3	36.1	32.6
Cubé-*Aresket*, 1–1600	47.2	41.6	45.4
Check	—	158.4	161.8
Nicotine-*Ultrawet*, 1–1200	48.8	52.7	46.4
Nicotine-*Aresket*, 1–1600	55.1	68.5	40.3

Treatments were discontinued July 1 because the plants were killed by downy mildew. The results showed (1) that addition of a spreader to cubé increased its effectiveness; (2) that *Ultrawet* at 1–1600 was more effective than at 1–800; (3) that *Ultrawet* was as effective as *Aresket;* and (4) that cubé with a suitable spreader was more effective than nicotine sulfate.

The second series of tests was made on an adjoining field of set onions which were not yet seriously affected by downy mildew. There was an average of from 348 to 537 thrips per plant before sprays were applied. Two treatments were made, on July 8 and 16. Table 2 shows the results, including the count made before spraying.

The temperature was abnormally high on the day the first spray was applied and for several succeeding days. Under

Table 2.—Average number of thrips per plant after spraying on July 8 and 16.

TREATMENT	JULY 8	JULY 10	JULY 19
Check	—	351.1	524.5
Cubé	370.9	124.5	568.2
Cubé-*Ultrawet*	348.7	111.2	255.9
Cubé-sulfur-*Ultrawet*	462.1	55.8	286.3
Sulfur-*Ultrawet*	537.1	168.4	450.6
Check	—	404.4	997.6

such conditions the sulfur alone killed many thrips and the combination of cubé, sulfur and *Ultrawet* was highly effective. However, the weather was much cooler when the second spray was applied, and the sulfur was not so effective. At the end of the test, cubé-*Ultrawet* was about as effective as cubé-sulfur-*Ultrawet*. Further spraying was prevented by downy mildew, which killed the onions.

The third series was applied on a small field of seed onions about two miles away from the fields of onions used in earlier tests. These seed onions had a small number of thrips per plant, and, in order to lessen reinfestation by migration, almost three-fourths of the field was sprayed. Sprays were applied July 16, 23 and 30 and August 6. No counts were made until three days following the second application, but one was made before spraying on July 30. The summary of results is given in table 3.

Table 3.—Average number of thrips per plant after spraying on July 16, 23 and 30 and August 6.

TREATMENT	JULY 26	JULY 30	JULY 31	AUGUST 7
Check	159.2	268.2	429.9	147.7
Cubé-*Ultrawet*	20.9	65.1	37.5	23.8
Cubé-sulfur-*Ultrawet*	34.4	116.4	65.4	—*
Check	90.5	—	582.1	200.6

* No count made, plants killed by downy mildew.

The number of thrips on untreated check plants actually decreased after July 31. This was due to the fact that thrips had seriously damaged those plants and there was little green tissue left. The initial number was low, and continued applications of cubé-*Ultrawet* kept the number at a low level. The addition of sulfur did not result in better control, and

the sulfur injured the onions slightly. After spraying was completed, the cubé-*Ultrawet* plot was distinctly greener than the other plots. A yield record kept by the grower showed that the cubé-*Ultrawet* plot yielded at the rate of 130 bushels per acre more than the adjoining untreated plot. Although the plots were not laid out to show differences in yield, this increase cannot be disregarded.

TEST ON CAULIFLOWER.—After downy mildew had killed these onions, the thrips migrated to a field of cauliflower nearby. This provided another opportunity for repeating the tests. The plants were sprayed on August 20, and counts made on 20 leaves on the following day. These sprays were applied by means of four-gallon, compressed-air sprayers. The summary of the results is given in table 4; the per cent mortality was obtained by comparing the average number of thrips on untreated leaves with the average number on treated leaves.

In this test the temperature was relatively high (93 degrees F.) and the addition of sulfur to cubé produced favorable results.

DISCUSSION.—The combination of pure ground cubé root with a suitable spreader apparently protected onion plants from thrips if spraying was begun before the plants were heavily infested. In the one series applied after heavy infestation, the reduction in number of thrips was not so satisfactory as in the other tests. The addition of sulfur increased the mortality in hot weather but apparently reduced it in cooler weather. Since these tests were conducted on irrigated fields, drought did not seriously affect the yield of onions, but the irrigation had no marked effect on the number of thrips.

Table 4.—Control of onion thrips on cauliflower.

TREATMENT	AVERAGE NUMBER THRIPS PER LEAF	PER CENT MORTALITY
Cubé spray	76.5	56.0
Cubé-*Ultrawet*, 1–1600	25.5	85.2
Cubé-*Aresket*, 1–1600	60.2	65.4
Cubé-sulfur-*Ultrawet*	21.5	87.9
Check—no treatment	174.0	

Since the productive parts of this work cover only one season, no final conclusions can be drawn as to the practical effectiveness of sprays containing pure ground cubé root and a suitable spreader. However, the use of such sprays offers promise as a control for onion thrips.—1-7-38.

LITERATURE CITED

Bourne, A. I. 1926. A study of the life history and control of the onion thrips. Mass. Ag. Exp. Sta. Bul. 227.

Horsfall, J. L., and F. A. Fenton. 1922. Onion thrips in Iowa. Iowa Ag. Exp. Sta. Bul. 205.

Maughan, F. B. 1934. Further studies on the control of the onion thrips. JOUR. ECON. ENT. 27(1):109–112.

Tate, H. D., and Floyd Andre. 1936. Laboratory studies on toxicity of nicotine and soap to gladiolus thrips and onion thrips. JOUR. ECON. ENT. 29(4):738–741.

Tests of Certain Materials as Controls for the Tomato Psyllid, *Paratrioza cockerelli* (Sulc.), and Psyllid Yellows

GEORGE M. LIST,* *Colorado Agricultural Experiment Station, Fort Collins*

The tomato psyllid, *Paratrioza cockerelli* (Sulc.), is often a limiting factor in tomato production in certain parts of Colorado. The feeding of the psyllid on the vegetation induces a condition known as "psyllid yellows," which affects plant growth and fruit production. During some seasons complete crop failures have resulted in many plantings.

Results have been published (List 1918) showing the effectiveness of liquid lime sulfur in controlling psyllid nymphs. At the same time attention was called to an injurious effect of the material upon the

* The author is indebted to Robert Hawkins for assistance in collecting parts of the data, to Andrew G. Clark, Mathematics Department, Colorado State College, for suggestions on analysis of the data and to Warren H. Leonard, Agronomy Department, Colorado State College, for critical review of the manuscript.

tomato plant. This tendency to cause injury has kept lime sulfur from coming into general use as a tomato spray. The material has, however, been recognized as a standard method for controlling this insect on potatoes (List & Daniels 1934; Daniels 1934). Recently (List 1935) it has been shown that sulfurs act as a very definite control without apparent injury to the plants.

The work herein reported was carried out during 1936 as two experiments. The object of Experiment I was to test the lethal effect of certain sulfurs and lime sulfurs upon psyllid nymphs, while Experiment II was designed to determine the comparative value of certain of these materials for (a) seasonal protection when used in definite treatment programs; (b) possible injurious effect upon tomato plants of the John Baer variety.

MATERIALS.—The materials and strengths used were (a) liquid lime sulfur, testing 33 degrees Baumé and carrying 32.2 per cent by volume of sulfide sulfur used at the rate of 1 gallon in 49 gallons of water; (b) dry lime sulfur guaranteed to contain 70 per cent calcium polysulfide applied at the rate of 1 pound in 10 gallons of water; (c) a 300-mesh dusting sulphur, undiluted; (d) a 300-mesh gashouse dusting sulfur, undiluted; and (e) a 300-mesh wettable sulfur used at the rate of 1 pound to 10 gallons of water.

METHODS.—The dusts were applied by means of a bellows type of hand duster, delivering the dusts into a cone-shaped canopy over the plant, until the latter became too large. All sprays were applied by means of a wheelbarrow type of hand sprayer, maintaining a pressure of approximately 150 pounds.

The tests in Experiment I were made in a field that had gone untreated and had developed a heavy late infestation. The four materials, with the untreated check, gave a series of five treatments. Five replications were used and arranged in a Latin square (Fisher 1932). This experimental design permits the removal of variation due to trends in infestation over the area tested, and facilitates the comparison of different treatments. The records consisted of counts of the live psyllid nymphs on two-ounce samples of leaves taken at random from each plot. The applications were made September 10, records being taken ten days later. In order to avoid a personal factor in sampling and counting, one person selected all samples and made all counts. In most cases the identity of a plot was not known until the data were recorded.

Experiment II, designed to determine the effect of materials upon the seasonal infestation, plant growth, the number, size and yield in pounds of fruit, was conducted in a planting of the John Baer variety grown at the rate of 1742 plants per acre. Four materials were applied in one, two and three applications with a check used for each; a total of 15 treatment variants resulted. Each series was replicated five times, with the plots arranged in randomized blocks to permit an analysis of variance. Each plot consisted of 12 plants, 8 of which were selected as the recorded plants, the other 4 being discarded. A detailed record was kept throughout the season of the number and weight of fruits from the recorded plants, together with the date of picking. Just before the first killing frost all green fruits were picked, weighed and counted. The effect upon plant growth was determined by general observations and by length measurements from the ground level to the terminal bud for the three longest branches of each plant. Seasonal population of psyllids was determined by counts of psyllid nymphs made upon two-ounce samples of leaves taken at random from each plot.

PSYLLID INFESTATION AND CONDITION OF THE PLANTS.—The plants from which the record yields were taken become naturally infested while in the cold frame. They were set in the field May 20 and, at that time, an occasional plant carried enough nymphs to produce symptoms of mild psyllid injury. Originally it had been planned to treat them about June 10, but a hail storm on June 4 destroyed most of the older leaves that bore the nymphs. Weather unfavorable for the psyllid followed, with the result that the infestation remained light until late summer. Subsequent to the break of hot weather in August, the population increased to the point where psyllid symptoms became apparent on untreated plants. This was typical for the region, where the general infestation was much below normal.

The first application of insecticides was made June 26. The fact that the plants were growing rather rapidly, fol-

lowing the hail injury, possibly made them somewhat more susceptible to spray injury. The second application was made July 7, when the plants were breaking over and blooming freely. The third application was made August 11, at a time when a few fruits were ripening.

The essential data are presented under experiment number.

RESULTS OF EXPERIMENT I.—The data for the lethal effect of the various insecticides on psyllid nymphs are presented in table 1 as mean numbers of live nymphs per plot sample for each treatment. An analysis of variance indicates that all treatments are highly significant, the odds being greater than 99:1 that the differences were not due to chance.

Table 1.—The lethal effect of sulfurs and lime sulfurs upon nymphs of the tomato psyllid.

TREATMENT	MEAN NUMBERS OF LIVE NYMPHS
1. Liquid lime sulfur	2.40
2. Wettable sulfur	9.80
3. Gashouse dusting sulfur	14.60
4. 300-mesh dusting sulfur	5.60
5. Check, untreated	210.80
Level of significance 5 per cent point	*39.63*

In order to make a closer comparison of the results from the different treatments, the check, which provided the greatest amount of variation, was dropped and the remainder of the data analyzed. The results failed to show any significant difference in effectiveness between treatments. One can conclude, therefore, that liquid lime sulfur, wettable sulfur, gashouse dusting sulfur and 300-mesh dusting sulfur gave almost equal and very effective kills under the conditions of this experiment.

RESULT OF EXPERIMENT II.—This test was a study of the effect of definite control programs with different insecticides upon psyllid population, plant growth, yield of fruit and quality of fruit. As the treatments appeared to have a greater effect on the early yield, the data taken before September 1 are first considered separately. When the aggregate data were analyzed, it was found in all cases that the differences between the treated and untreated plots were highly significant. Therefore, except in the study of the effect upon plant growth, the data afforded by the check plot were excluded in order to permit a closer comparison for the different materials. The data are summarized in table 2.

EFFECT OF TREATMENTS UPON PSYLLID INFESTATION.—The analysis of variance for the number of psyllid nymphs on uniform plot samples of leaves taken from treated plants is given in table 3.

Since the F-value* for treatments does not equal the 5 per cent point, the experiment has failed to show any differences

* F = Ratio of greater variance to the smaller variance, the latter usually being that due to error (Snedecor 1934).

Table 2.—Summarized data taken in a study of sulfurs and lime-sulfurs for the control of the psyllid, *Paratrioza cockerelli* (Sulc.), on tomatoes.

ITEMS	TREATMENTS					
	Check, Untreated	Dry Lime Sulfur	Wettable Sulfur	300-Mesh Dusting Sulfur	Liquid Lime Sulfur	Level of Significance (5 Per Cent Point)
Mean number nymphs per plot sample	157.730	60.130	61.200	79.200	58.860	
Mean length of plant growth (in inches)	17.220	14.040	17.260	17.110	14.820	1.070
August mean total yield (in pounds)	53.370	39.980	58.840	60.470	41.680	5.560
August mean number fruits	214.460	155.130	221.330	220.460	154.660	22.560
August mean weight individual fruits (in pounds)	0.250	0.260	0.267	0.273	0.270	0.017
Season's mean total yield (in pounds)	161.490	155.560	164.150	174.740	152.100	10.830
Season's mean number fruits	725.930	617.930	686.130	710.530	601.000	28.320
Season's mean weight individual fruits (in pounds)	0.216	0.253	0.239	0.245	0.250	0.011
Total mean number fruits (ripe and green)	*1289.400*	*1059.530*	*1121.260*	*1172.600*	*1070.730*	*47.500*

Table 3.—Analysis of variance for the number of psyllid nymphs on uniform plot samples of leaves taken from treated plants.

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES FREEDOM	MEAN VARIANCE	STANDARD ERROR	F†
Treatments	4,333.38	3	1,444.44		1.18
Applications	42,223.30	2	21,111.65		12.36**
Treatment×application	10,312.57	6	1,718.76		1.00
Blocks	15,152.26	4	3,788.06		2.21
Error	75,124.34	44	1,707.37	41.33	
Total	*147,145.85*	*59*			

† F = Ratio of greater variance to the smaller variance, the latter usually being that due to error.
** Highly significant; *i.e.*, exceeds the 1 per cent point.

in effectiveness for liquid lime sulfur, dry lime sulfur, wettable sulfur and dusting sulfur.

It should be repeated that a separate analysis with the check included as a treatment indicates that all chemical treatments resulted in significantly lower nymph counts than the check.

The application means indicating the average number of nymphs on the uniform samples of leaves toward the close of the season are as follows: one application, 93; two applications, 72.5; three applications, 29.35 nymphs. The variance analysis indicates a highly significant effect of applications. A more detailed comparison shows a difference between one and two applications which approaches significance. The differences resulting from three applications as against two applications or one application are highly significant.

It appears clear, therefore, that one application of dry lime sulfur, liquid lime sulfur, wettable sulfur and 300-mesh dusting sulfur, applied June 26, had a very marked effect upon the September infestation of psyllids, with no marked differences appearing in the effectiveness of these materials. Two applications increased the effectiveness to a point approaching significance, while three applications increased the effectiveness very significantly.

EFFECTS OF TREATMENT UPON PLANT GROWTH.—Following the first application it was noted that the liquid and dry lime sulfurs had caused some injury to the plants. This was shown by definite burning of the tips and, in some cases, the bases of the small leaflets. The midrib area at the bases of younger leaves was often scorched.

Many leaves without definitely blackened areas curled after growth resumed, indicating that growth had been stopped in certain areas. In some cases, the terminal buds were killed. All plants showed a stunted condition that was apparent for several days. Such pronounced injury was not noted after the second and third applications.

Plant measurements made 11 days after the first application of insecticides are given in table 2. An analysis of variance indicates a significant difference in plant growth as a result of treatment. In the comparison of the treatment means given in table 2, no differences are found in plant growth between the untreated check plots and those treated with wettable sulfur and dusting sulfur. However,

Table 4.—Analysis of variance for the August yields in pounds of tomatoes from plants treated with sulfurs and lime sulfurs.

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES FREEDOM	MEAN VARIANCE	STANDARD ERROR	F†
Treatments	5359.3642	3	1786.4547		30.81**
Applications	25.4793	2	12.7396		4.55
Treatment×application	283.2252	6	47.2042		1.22
Blocks	1150.8682	4	287.7170		4.96
Error	2551.0178	44	57.9776	7.61	
Total	*9369.9547*	*59*			

† F = Ratio of greater variance to the smaller variance, the latter usually being that due to error.
** Highly significant; *i.e.*, exceeds the 1 per cent point.

it is proved that the dry lime sulfur and liquid lime sulfur treatments seriously retarded plant growth.

EFFECT OF TREATMENTS UPON EARLY FRUIT.—The analysis of variance for the August yields in pounds of tomatoes from plants treated with sulfurs and lime sulfurs is given in table 4. A summary of other computations appears in table 5.

Table 5.—Summary of analysis of variance of the average weight of fruits, the yield in pounds and numbers of fruits from plants treated with sulfurs and lime sulfurs.

VARIATION IN	TREATMENTS	F-VALUE FOR APPLICATIONS	TREATMENT×APPLICATION
August yield in pounds of fruits	30.81**	4.55	1.23
August yield in number of fruits	22.81**	1.44	1.78
Average weight of August fruits	1.11	1.08	
Seasonal yield in pounds	6.95**	1.44	1.27
Seasonal yield in numbers of fruits	27.22**	1.19	7.75**
Average weight of season's fruits	2.37*	9.24**	3.10*
Seasonal yield in numbers of ripe and green fruits	9.54**	2.56	1.65

† F = Ratio of greater variance to the smaller variance, the latter usually being that due to error.
* Significant; *i.e.*, exceeds the 5 per cent point.
** Highly significant; *i.e.*, exceeds the 1 per cent point.

It is clear that there is a significant difference in yield due to treatments. By comparing the mean yields as given in table 2, the wettable sulfur and dusting sulfur are demonstrated superior to the check, while dry and liquid lime sulfur are inferior.

With these significant differences it seems safe to conclude that the wettable sulfur and sulfur dust, by controlling the light psyllid infestation without causing spray injury, resulted in a marked increase in August fruit yield over the check. Even though they gave an equal control of the psyllids the dry and liquid lime sulfurs caused so much injury that the yield was distinctly lower.

There is no significant difference in yield between applications, indicating that the major portion of the injury from the lime sulfurs came from the first application. This is in accordance with observations during previous years. The plants may become somewhat more resistant to lime sulfur injury after the first application; the slow late summer growth is undoubtedly more resistant than the rapid early season growth.

The F-value for treatments in the analysis of data relating to the number of early fruits, table 5, indicates a highly significant difference between treatments. The plots treated with lime sulfurs produced the lowest number of early fruits.

From table 5, it is obvious that the treatments do not markedly affect the fruit size. However, an analysis with the check included indicated that the fruits from the check are smaller. These data, therefore, indicate (1) that the control of even a light infestation of psyllids resulted in larger fruit; (2) that the injurious effect of dry and liquid lime sulfurs upon the yield of early fruit was a retardation of setting and ripening and not a retardation of the fruit growth.

EFFECT OF TREATMENTS UPON FRUITS HARVESTED DURING ENTIRE SEASON.—It is evident from table 5 that there is a highly significant difference in seasonal yield due to treatments. Comparison of the yield means, table 2, shows the dusting sulfur superior to dry and liquid lime sulfur. The difference in yield between dusting and wettable sulfur plots approaches significance, with the dusting sulfur giving the higher yield. The differences in yield means are not so highly significant as with the early fruit. This again indicates that the injurious effects of dry and liquid lime sulfurs were produced largely by the early season applications and were being overcome by the plants as the season advanced.

Table 5 shows a pronounced variation in seasonal yield in numbers of fruits produced by the treatments. While there is no significant difference in the effect of dry and liquid lime sulfurs, both are significantly lower than the sulfur treatments and check. There is a real difference in the number of fruits produced by the check plots and that from sulfur dust plots.

The experiment has failed to show a significant effect of treatments on fruit size. However, the analysis with check included indicated that the tomatoes from the untreated checks were definitely smaller.

It is important to note (table 5) the highly significant effect of applications upon fruit size. The application means for fruit size are, one application, 0.246 pounds; two applications, 0.237 pounds; three applications, 0.258 pounds. No significant difference resulted between the one and two applications means, but as the fruits from the three application plots are definitely larger it may be concluded that the third application, by controlling the late infestation of psyllids, permitted larger fruits to develop on the plots treated

EFFECTS OF TREATMENTS UPON THE TOTAL NUMBER OF FRUITS SET DURING SEASON.—It has been often noticed that one of the symptoms on bearing tomato plants of a moderate infestation of psyllids is a stimulation of both blooming and fruiting. The present experiment, as evidenced by the total number of fruits set during the entire season, substantiates this conclusion. (See table 2.) The analysis of the data with the check included indicated that the increase in number of fruits on the check is highly significant. The analysis without the check, as given in table 5, shows a highly significant difference between treatments. The low numbers from the lime sulfur plots may be attributed to plant injury since no difference was otherwise shown in psyllid control by the various treatments.

Table 6.—The yield in pounds of tomatoes produced by plants treated with sulfurs and lime sulfurs for tomato psyllid control.

TREATMENT	AUGUST YIELD PER ACRE IN POUNDS	SEASON'S YIELD PER ACRE IN POUNDS
1. Check	11,624.5	35,172.1
2. Dry lime sulfur	8,707.6	33,880.9
3. Wettable sulfur	12,816.7	35,752.4
4. 300-mesh dusting sulfur	13,171.6	38,058.3
5. Liquid lime sulfur	9,079.2	33,127.3

Table 6 gives the yield computed on an acre basis. The August fruit yield is given separately since the greatest differences between treatments occurred early in the harvest season.

No difference in control was apparent when dry and liquid lime sulfurs were used, but both gave lower yields than the untreated check. This would not be true under conditions of heavy infestation when the check yield was reduced to a greater extent by psyllid injury. Under such conditions the net gain from lime sulfurs would undoubtedly be higher in comparison with the untreated check. No clear difference in the acre yield between the wettable sulfur and dusting sulfur plots is shown, but an increase over the check is clear. The large margin of difference in pound yield between the sulfurs and lime sulfurs appears to be due to plant injury by the latter.

CONCLUSIONS.—No marked differences in tomato psyllid kills were obtained through the use of dusting sulfur, gashouse sulfur, wettable sulfur, dry lime sulfur and liquid lime sulfur. All gave high kills as shown by nymph counts.

Dusting sulfur, wettable sulfur, dry lime sulfur and liquid lime sulfur gave no significant differences in seasonal protection against the tomato psyllid as estimated from population counts made during the harvest period.

Three applications were more effective in controlling the tomato psyllid and preventing psyllid yellows than one and two applications.

Dry lime sulfur and liquid lime sulfur sprays seriously retarded plant growth and setting of fruit of John Baer tomatoes. Lime sulfur sprays resulted in reduced yields when compared to the untreated checks due, apparently, to plant injury.

Dusting and wettable sulfurs gave an increase in yield over that of the untreated checks and were found in these tests to be satisfactory insecticides.—1-7-38.

LITERATURE CITED

Daniels, L. B. 1934. The tomato psyllid and the control of psyllid yellows of potatoes. Colo. Exp. Sta. Bul. **410**: 20. 6 figs.

Fisher, R. A. 1932. Statistical methods for research workers. Fourth ed., 296 pp., bibliog., index. Oliver and Boyd, Edinburg.

List, George M. 1918. Test of insecticides. Cir. Colo. State Ent. **26**: 36–45.

List, George M. 1935. Psyllid yellows of tomatoes and control of the psyllid, *Paratrioza cockerelli* (Sulc.), by the use of sulfur. JOUR. ECON. ENT. **28**: 431–6. 3 figs.
List, George M., and L. B. Daniels. 1934. A promising control for psyllid yellows of potatoes. Science 79(2039):79.
Snedecor, George W. 1934. Calculation and interpretation of analyses of variance and covariance. 87 pp., bibliog. Collegiate Press, Ames, Ia.

Two Years of Study of the Effects of Root Nematode on the Yield of Canning Tomatoes[1]

G. A. FICHT,[2] *Purdue University Agricultural Experiment Station, West Lafayette, Ind.*

The presence of root nematode *Heterodera marioni* (Cornu.)[3] in tomato plants originating in southern states has been frequently noted. Most of the tomato plants grown in the South and shipped into Indiana are brought in by canning companies and are used almost entirely for the production of canning tomatoes. Since this is the case, these experiments have dealt with the effects of the nematode on the yield of canning fruits. The results of the experiments, had market tomatoes been taken into consideration, might have been different, as the canning grades are based almost entirely on color and soundness, and the size of the fruits is not a consideration in determining canning grades.

PLAN AND CONDUCT OF EXPERIMENT.—Free and infested plants of four varieties were received from Georgia on May 28 and June 1, 1936, and were planted at Auburn, Ind., May 29 and June 2. In 1937, two varieties were received on May 23 and were planted on May 24 and 25. As an additional check a series of plots of home-grown plants was used during the latter season. Plants which died were replaced a week following the original setting of the plants.

During 1936, a modified Latin square plot arrangement was used consisting of four replications of 40 hill plots. In 1937, a true Latin square arrangement was used. Each of the plots contained 25 plants.

Pickings were made twice weekly from July 21 to October 14 in 1936 and from August 13 to September 30 in 1937. These periods represented the active canning seasons at Auburn. They also marked the period of the production of ripe fruit of canning quality. All ripe tomatoes picked throughout the canning season were graded by an experienced tomato grader according to U. S. canning grades, as either no. 1, no. 2 or cull fruits. The fruits of each grade were counted and weighed. At the end of the canning season the green fruits were picked, classified as sound and unsound, and counted and weighed.

Following the picking of the green fruit, the roots were dug and classified into three groups according to the severity of the infestation and the condition of the roots. Lightly infested plants consisted of that group in which the main roots were not enlarged but which had secondary roots showing the presence of knots or galls indicating infestation. Plants classified as having a medium infestation were those on which the primary roots were greatly enlarged and badly knotted but were still alive and functioning. Heavily infested plants were designated as those on which the main roots were greatly enlarged and knotted, were wholly or partially decayed and had ceased to function.

SEVERITY OF INFESTATION.—No attempt was made at the time of planting to classify the roots on the basis of their degree of infestation. In 1936, the plants used were very severely infested and the primary roots were, in most cases, already

[1] This paper reports the results of cooperative studies conducted by the Department of Entomology, Purdue University Agricultural Experiment Station, the Department of Botany, Purdue University Agricultural Experiment Station, and the Division of Entomology, Department of Conservation, at the Indiana State Corn Borer Station at Auburn, Ind.

[2] The writer is indebted to R. W. Samson, Department of Botany, for assistance in supplying free and infested plants from Georgia, for the provision of an experienced grader to grade the fruits and for advice on other matters; also to P. T. Ulman and A. W. Trippel of the Division of Entomology, Department of Conservation, for supplying land and other forms of assistance during the conduct of the work.

[3] Class Nematoda, family Anguillulidae.

Table 1.—Degree of infestation of tomato roots at the end of harvest.

VARIETY	WHERE GROWN	YEAR	FREE OR INFESTED	PER CENT LIGHTLY INFESTED	PER CENT MEDIUM INFESTATION	PER CENT HEAVILY INFESTED	TOTAL PER CENT INFESTED
Baltimore	Georgia	1936	Free	0.00	0.00	0.00	0.00
Baltimore	Georgia	1936	Infested	11.25	31.25	57.50	100.00
Pride of Illinois	Georgia	1936	Free	1.25	0.00	0.00	1.25
Pride of Illinois	Georgia	1936	Infested	3.75	23.75	72.50	100.00
Marglobe	Georgia	1936	Free	2.50	0.00	0.00	2.50
Marglobe	Georgia	1936	Infested	5.00	42.50	52.50	100.00
Pritchard	Georgia	1936	Free	0.00	0.00	0.00	0.00
Pritchard	Georgia	1936	Infested	16.25	25.00	58.75	100.00
Baltimore	Indiana	1937	Free	0.00	0.00	0.00	0.00
Baltimore	Georgia	1937	Free	0.00	0.00	0.00	0.00
Baltimore	Georgia	1937	Infested	19.36	60.48	20.16	100.00
Marglobe	Georgia	1937	Free	0.00	0.00	0.00	0.00
Marglobe	Georgia	1937	Infested	28.10	51.23	20.67	100.00

abnormally enlarged and knotted. The plants used in 1937 were less severely infested. The primary roots showed no visible signs of enlargement, and the infestation was evident only from the nodules occurring on the secondary roots.

The results of the more severe infestation at planting time in 1936 was reflected in the larger number of plants which required resetting. During that season there were indications that the infested plants were weakened to such an extent that more replants were necessary to produce full stands. A total of 1.56 per cent of the infested plants did not survive planting, while only .16 per cent of the free plants needed resetting. During the 1937 season only one plant in each of the five treatments required resetting. The variation in the weather conditions of the two seasons may have had some effect on the number of plants requiring resetting.

During 1936, 100 per cent of the plants in the supposedly infested plots were found to be infested at the end of harvest and .94 per cent of the plants in the supposedly free plots were found to be lightly infested. During 1937 all supposedly free plants were free of infestation at the completion of harvest and 100 per cent of the supposedly infested plants showed some degree of infestation. The roots showed a higher degree of damage at digging time in 1936 than in 1937, table 1. During the previous season, 9.06 per cent were lightly infested, 30.82 per cent showed medium infestation and 60.31 per cent were heavily infested. During the latter season, 23.72 were lightly infested, 55.85 showed medium infestation and only 20.41 per cent were classified as heavily infested, according to the grouping used.

NUMBER OF FRUITS SET.—The total number of fruits which were set on the plants averaged 16.61 per cent less on infested than on free plants during the two seasons. All varieties showed reductions in the set of fruit during both seasons, table 2. All varieties used during 1936 averaged 17.13 per cent less tomatoes on the infested than on the uninfested plants,

Table 2.—Comparison of the number of fruits set on free and infested plants.

VARIETY	YEAR	NUMBER OF FRUITS SET PER ACRE ON FREE PLANTS	NUMBER OF FRUITS SET PER ACRE ON INFESTED PLANTS	PER CENT DECREASE IN NUMBER OF FRUITS SET PER ACRE ON INFESTED PLANTS
Baltimore	1936	194,267	158,809	18.34
Pride of Illinois	1936	157,526	116,369	26.12
Marglobe	1936	201,288	165,539	17.76
Pritchard	1936	243,767	228,401	6.31
Baltimore*	1937	131,917		
Baltimore	1937	182,568	164,647	9.81
Marglobe	1937	213,428	167,882	21.34

* Home-grown plants.

and the two varieties used during 1937 averaged 15.57 per cent less. The greatest decrease in the number of fruits set occurred on the Pride of Illinois variety in 1936, and the smallest decrease on the Pritchard variety during the same season.

The decrease in the number of fruits set on the plants was due probably to the decreased size of the infested plants, fig. 1, and their comparatively unthrifty condition. During the dry, hot season of1936, fig. 2, many of the infested plants wilted during the heat of the day in June, July and early August but recovered at night and were able to produce a reasonable crop of fruit after the rainfall became more abundant about the middle of August. This wilting was not evident during the cooler, wetter conditions of 1937, although a noticeable reduction in the size of the plants was evident during this season.

FIG. 1.—Comparative size of free and infested plants during the season of blossoming and setting of fruit. Right, free plot of Marglobe; left, infested plot of Marglobe.

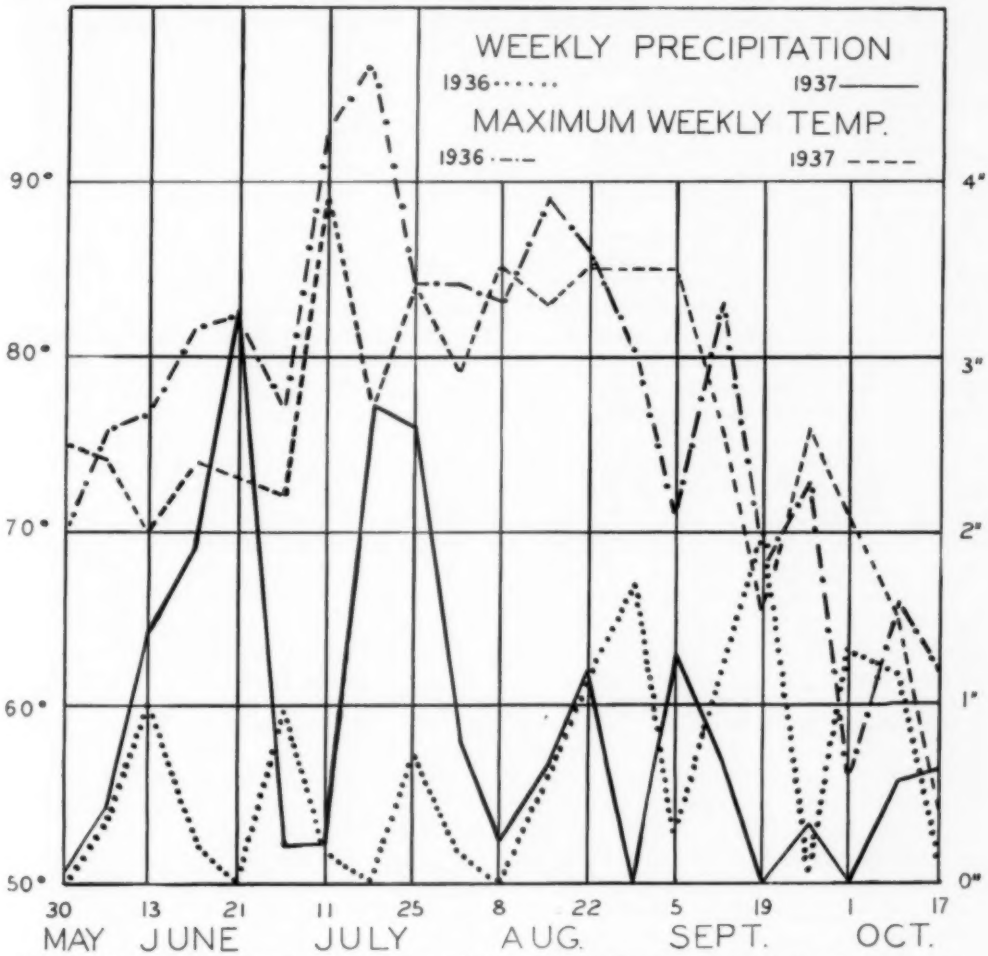

FIG. 2.—Comparative temperature and precipitation from planting to harvest during the two years of study of the effects of root nematode on tomato yields.

PROPORTION OF SET FRUIT WHICH RIPENED.—It will be noted, table 3, that there was an increase in the percentage of set fruit which ripened on the infested plants of all varieties studied during 1936 and that in 1937 there was a small decrease. This condition may be accounted for in several ways. During the 1936 season, the plants used in the experiment were more severely infested and a higher percentage was classified as heavily infested at the end of harvest. This classification indicated premature death of the plants and thus premature ripening of the fruits.

Another factor which contributed to this condition was the heavy infestation of early blight which occurred during 1936. All plants lost their foliage before the end of the picking season, but plants infested with nematode exhibited less resistance to the disease and defoliation occurred earlier in the season on such plants. During 1937 most of the foliage was retained by both uninfested and infested plants until after the ripe fruit had been harvested. The drought conditions which existed during the previous season may have contributed to premature death of the plants and the premature ripening of their fruit. In spite of an average increase of 5.32 per cent in the total set of fruit which ripened during 1936, the total number of ripe fruits of all grades was lower on the infested plants.

SIZE OF FRUITS OF ALL GRADES.—Calculations of the average size of the tomatoes of all of the five grades show a definite trend toward a decrease in the size of the fruits from plants infested with root nematodes, table 4. In only one instance did the average size of all classes of fruit average smaller from the free than from the infested plants. This instance was the Marglobe variety used during 1937. During 1936 the average size of the fruits of marketable grades was larger from free than from infested plants in all cases except that of the size of no. 2 fruits of the Pritchard variety used. An average decrease of 5.61 per cent in the size of the fruits occurred on infested plants during 1937 and 7.10 per cent in 1936. The average decrease of all varieties during the two years was 6.10 per cent. The decreased size may have been partially accounted for by the smaller number of fruits set on the infested plants. Differences in the size of canning fruits are important as they affect the yield only, since the greater portion of the canning trade produces tomato pulp.

YIELD OF NO. 1 TOMATOES.—In three of the four varieites, uninfested plants produced higher yields of U. S. no. 1 canning fruits during 1936 than did the infested plants of the same varieties. However, the Pritchard variety produced a higher yield of fruits of this grade from the infested than from the free plants.

Table 3.—Number and percentage of fruits of all grades which ripened in nematode infested and free plots.

VARIETY	YEAR	FREE OR INFESTED	TOTAL NUMBER OF FRUITS SET PER ACRE	TOTAL NUMBER OF FRUITS WHICH RIPENED PER ACRE	PER CENT OF TOTAL SET WHICH RIPENED	INCREASE OR DECREASE IN PER CENT OF FRUITS WHICH RIPENED
Baltimore	1936	Free	194,267	90,501	46.62	
Baltimore	1936	Infested	158,809	86,961	54.76	+ 8.14
Pride of Illinois	1936	Free	157,526	95,266	60.47	
Pride of Illinois	1936	Infested	116,369	79,803	68.58	+ 8.11
Marglobe	1936	Free	201,288	65,838	32.71	
Marglobe	1936	Infested	165,539	79,550	48.06	+15.35
Pritchard	1936	Free	243,767	114,832	47.11	
Pritchard	1936	Infested	228,401	117,672	51.53	+ 4.42
Baltimore*	1937	Free	131,917	63,121	47.85	
Baltimore	1937	Free	182,568	78,503	42.95	
Baltimore	1937	Infested	164,647	63,420	38.52	− 4.43
Marglobe	1937	Free	213,428	67,825	31.78	
Marglobe	1937	Infested	167,882	50,452	30.05	− 1.73

* Home-grown plants.

Table 4.—Average weight of tomato fruits of each of the five grades harvested, in pounds.

VARIETY	YEAR	FREE OR INFESTED	AVERAGE WEIGHT OF NO. 1 CANNING GRADE	AVERAGE WEIGHT OF NO. 2 CANNING GRADE	AVERAGE WEIGHT OF RIPE CULLS	AVERAGE WEIGHT SOUND GREEN FRUIT	AVERAGE WEIGHT UNSOUND GREEN FRUIT	AVERAGE WEIGHT OF ALL GRADES OF FRUIT	PER CENT DECREASE OR INCREASE IN TOTAL WEIGHT OF FRUIT
Baltimore	1936	Free	.372	.337	.288	.190	.124	.262	
Baltimore	1936	Infested	.337	.325	.263	.159	.119	.240	− 8.39
Pride of Illinois	1936	Free	.393	.394	.314	.202	.132	.285	
Pride of Illinois	1936	Infested	.374	.355	.285	.197	.135	.269	− 5.61
Marglobe	1936	Free	.366	.334	.247	.165	.102	.243	
Marglobe	1936	Infested	.334	.326	.269	.143	.091	.233	− 4.11
Pritchard	1936	Free	.305	.267	.232	.147	.087	.208	
Pritchard	1936	Infested	.291	.271	.230	.136	.075	.201	− 4.32
Baltimore*	1937	Free	.345	.338	.245	.167	.139	.247	
Baltimore	1937	Free	.314	.305	.230	.216	.178	.249	
Baltimore	1937	Infested	.306	.304	.229	.197	.079	.223	−10.44
Marglobe	1937	Free	.313	.313	.313	.139	.118	.239	
Marglobe	1937	Infested	.309	.309	.292	.157	.173	.248	+ 3.76

* Home-grown plants.

This variety was very severely infested with nematodes and was severely defoliated by early blight. The premature death of the plants due to nematode infestation and the earlier defoliation of the infested plots as a result of early blight enabled this variety to ripen a larger proportion of its fruit in the infested plots than in the free plots, with the consequent increase in the yield of no. 1 canning fruits, table 5.

In 1937, both the Baltimore and Marglobe varieties produced lower yields, table 5, from infested than from free plants, the Marglobe variety seemingly being less resistant to the nematode than the former variety.

YIELD OF NO. 2 TOMATOES.—During 1936 the yield of fruit of no. 2 canning grade, largely placed in this grade because of lack of color and the presence of water cracks on the stem ends, was reduced on all varieties but not to the same extent as the no. 1 fruits of the Baltimore, Pride of Illinois and Marglobe varieties. None of the four varieties produced an increased yield of this grade of fruit in the infested plots, table 6. Stem-end rot, caused by early blight, produced a small proportion of no. 2 fruits during this season as all of the plots were infected with this disease. The average yield of the four varieties used during the 1936 season was reduced by 4.89 per cent in this grade of tomatoes.

The two varieties used during 1937 produced yield reductions from infested plots which were greater than that of the no. 1 canning grade. The average reduction was 27.66 per cent. In addition to the lack of color and the presence of water cracks on the stem ends which often transfer fruits from the no. 1 to the no. 2 grade, a severe infestation of anthracnose

Table 5.—Yield of fruits of U. S. canning grade no. 1 from free and infested plants.

VARIETY	YEAR	POUNDS PER ACRE IN FREE PLOTS	POUNDS PER ACRE IN INFESTED PLOTS	POUNDS INCREASE OR DECREASE IN FREE OVER INFESTED PLOTS	PER CENT INCREASE OR DECREASE OF FREE OVER INFESTED PLOTS
Baltimore	1936	14,110	12,671	+1,439	+10.20
Pride of Illinois	1936	14,785	10,791	+3,994	+27.01
Marglobe	1936	13,301	10,916	+2,385	+17.93
Pritchard	1936	16,932	17,952	−1,020	− 5.68
Baltimore*	1937	12,084			
Baltimore	1937	13,296	11,064	+1,020	+ 7.67
Marglobe	1937	11,912	9,194	+2,718	+22.82

* Home-grown plants.

Table 6.—Yield of U. S. no. 2 canning tomatoes in free and infested plots.

VARIETY	YEAR	POUNDS PER ACRE IN FREE PLOTS	POUNDS PER ACRE IN INFESTED PLOTS	POUNDS INCREASE IN YIELD OF FREE OVER INFESTED PLOTS	PER CENT INCREASE IN YIELD OF FREE OVER INFESTED PLOTS
Baltimore	1936	12,166	11,719	447	3.67
Pride of Illinois	1936	13,630	13,020	610	4.48
Marglobe	1936	8,716	7,794	822	9.43
Pritchard	1936	10,364	10,148	216	2.08
Baltimore*	1937	7,873			
Baltimore	1937	8,995	7,196	1,780	20.01
Marglobe	1937	7,445	4,816	2,628	35.31

* Home-grown plants.

contributed a considerable proportion of fruit to this grade which otherwise might have been classified as no. 1 canning tomatoes.

YIELD OF RIPE CULLS.—Cull fruits were caused by several factors. A lack of color placed many fruits in this unmarketable grade. Occasional tomatoes became over-ripe. During 1936, many fruits were placed in this grade as a direct or indirect result of the feeding of the tomato hornworm, and a severe infestation of early blight produced many fruits which bore early blight lesions. In 1937, while early blight was present in both infested and uninfested plantings, the number of fruits placed as culls from this cause was relatively small. Anthracnose lesions were plentiful during the 1937 season and were responsible for a large part of the cull fruits, especially during the peak of the picking season.

An average yield reduction of 30.25 per cent occurred on the infested plants of the four varieties grown during 1936, and an average reduction of 37.33 per cent occurred in the yield of ripe cull fruits of the two varieties grown in 1937. All varieties had lower yields of fruits of this grade in the plots infested with nematode than in those plots which were free of nematode. During both seasons the reduction in the yield of culls by infested plants was more marked than in the yield of the first two marketable grades of canning tomatoes, table 7. Sun scald produced some culls during a small portion of the picking season.

YIELD OF SOUND GREEN FRUIT.—Green fruit left after the completion of the canning season is mostly worthless as a commercial crop. However, the yield of such fruit must be taken into consideration in the calculation of the effect of root nematode on the tomato yield. The time of setting of the plants, the time of occurrence of frost in the fall, the effect of weather at the time the fruits are being set and ripened, and the premature death of the plants due to nematode infestation or disease are influences which have an effect on the amount of green fruit left after the canning season is over.

The yield of sound green fruit was greatly reduced on all infested varieties during the 1936 season. In 1937 there was

Table 7.—Yield of ripe cull fruits appearing during the regular twice weekly pickings.

VARIETY	YEAR	POUNDS PER ACRE IN FREE PLOTS	POUNDS PER ACRE IN INFESTED PLOTS	POUNDS PER ACRE REDUCTION IN YIELD OF INFESTED PLOTS	PER CENT REDUCTION IN YIELD OF INFESTED PLOTS
Baltimore	1936	4,842	3,559	1,283	26.84
Pride of Illinois	1936	7,080	4,118	2,962	41.84
Marglobe	1936	4,016	2,547	1,218	37.28
Pritchard	1936	5,015	4,126	889	17.75
Baltimore*	1937	1,645			
Baltimore	1937	1,506	1,045	460	30.58
Marglobe	1937	1,513	846	667	44.08

* Home-grown plants.

Table 8.—Yield of sound green fruit remaining at the end of the canning season.

VARIETY	YEAR	POUNDS PER ACRE ON FREE PLANTS	POUNDS PER ACRE ON INFESTED PLANTS	POUNDS PER ACRE INCREASE OR DECREASE ON INFESTED OVER FREE PLANTS	PER CENT INCREASE OR DECREASE ON INFESTED PLANTS AS COMPARED WITH FREE PLANTS
Baltimore	1936	16,834	11,768	−5,066	−30.09
Pride of Illinois	1936	10,191	5,429	−4,762	−46.73
Marglobe	1936	16,955	11,866	−5,089	−30.01
Pritchard	1936	14,463	11,337	−3,126	−21.61
Baltimore	1937	19,825	20,299	+ 474	+ 2.33
Marglobe	1937	15,877	15,422	− 455	− 2.87
Baltimore*	1937	9,508			

* Home-grown plants.

no significant difference in the yield of this grade of tomatoes, table 8.

YIELD OF GREEN CULL FRUIT.—Fruits classified as green culls were those which were not yet ripe enough for canning at the end of the canning season and which were, for some reason or other, unsound. The chief reasons for their unsoundness in 1936 were the feeding of the tomato hornworm and the presence of early blight lesions. During 1937 the same factors were responsible for the production of unsound green culls. In addition to these two factors, anthracnose contributed to placing green fruits in this grade. The hornworm was the most important factor in 1936, but the other influences were of about equal importance during the following season. Water cracks on the stem ends in which moulds frequently developed were responsible for a very small proportion of the green fruits being classified as unsound.

Reductions in the yield of unsound green fruits occurred in all four varieties infested with nematodes in 1936 and in one of the two varieties used during 1937. During the latter season, the Baltimore variety showed an increase in the yield of fruits of this class, table 9. The canning season was cut chort by early frosts; also the lack of premature death and defoliation due to severe infestation and disease, in which premature ripening occurred only to a slight extent, probably accounted for a large part of the crop being left in the field at the end of the regular harvesting period. The weakened condition of the plants, with the subsequent increase in the severity of disease conditions, especially early blight, seemed to increase the proportion of unsound fruits in the infested Baltimore variety. Anthracnose was also distinctly more prevalent on and destructive to the fruits of this variety during 1937 than to the Marglobe variety.

TOTAL YIELD OF ALL GRADES OF FRUIT.—A summary of the total yield of all grades of fruit, including both green and ripe, shows a distinct advantage in production for those plants which are free of nematode, table 10, during both years of study. The greatest difference in yield between infested and uninfested plants during the 1936 season occurred in the

Table 9.—Yield of unsound green fruit left in the field at the completion of the canning season.

VARIETY	YEAR	POUNDS PER ACRE FROM FREE PLANTS	POUNDS PER ACRE FROM INFESTED PLANTS	INCREASE OR DECREASE IN POUNDS PER ACRE FROM INFESTED PLANTS	PER CENT INCREASE OR DECREASE FROM INFESTED PLANTS AS COMPARED WITH FREE PLANTS
Baltimore	1936	1,911	1,349	−562	−29.41
Pride of Illinois	1936	1,578	1,232	−346	−21.93
Marglobe	1936	1,968	1,583	−385	−19.56
Pritchard	1936	2,728	2,118	−610	−22.36
Baltimore	1937	617	1,025	+408	+39.81
Marglobe	1937	816	766	− 50	− 6.09
Baltimore*	1937	625			

* Home-grown plants.

Table 10.—Total yield of all grades of fruit, both green and ripe, from infested and uninfested plants.

Variety	Year	Pounds of Fruit Per Acre on Uninfested Plants	Pounds of Fruit Per Acre on Infested Plants	Decrease in Pounds of Fruit Per Acre on Infested Plants	Per Cent Decrease in Yield of Fruit Per Acre
Baltimore	1936	49,863	41,066	8,795	17.24
Pride of Illinois	1936	47,264	34,590	12,674	26.82
Marglobe	1936	45,001	34,406	10,595	23.54
Pritchard	1936	49,502	45,681	3,821	7.72
Baltimore	1937	44,239	41,029	3,211	7.26
Marglobe	1937	37,564	31,045	6,519	17.35
Baltimore*	1937	31,735			

* Home-grown plants.

Pride of Illinois variety. In this variety there was a difference of approximately six and one-half tons of fruit per acre. It will be noted that differences in yield are much greater between free and infested plants when all grades of fruit are taken into consideration than when only marketable ripe fruits are considered.

It will be noted, also, that there is a marked difference in the per cent of decrease in yield between the free and infested plants of the several varieties. In the 1936 studies, the Pritchard variety was outstanding in the production of all classes of fruit when considered from the point of view of yield reductions due to nematode. Pride of Illinois appears to be more susceptible to attack, when considered from the point of view of yield, than are the other strains. However, the earliness or lateness of the various strains used has an important bearing on their yields and the varieties used during the two years are not comparable in this respect. Also, the severity of infestation, disease conditions which produce premature defoliation, and climatic conditions have an important bearing on the yields produced.

The two strains which were used during 1937 showed a great difference in yield. These two strains are not entirely comparable, as the Marglobe variety is a late one which is grown largely in southern Indiana, while the Baltimore variety is the most widely grown variety in the northern part of the state, where these experiments were conducted. The home-grown Baltimore used in 1937 was an earlier strain than the Baltimore received from the south.

Per Acre Value of Marketable Tomatoes.—The marketable tomatoes which included the fruits classed as U. S. grades no. 1 and no. 2, table 11, had a per acre value of $32.01 less on the infested than on the free plants of the Pride of Illinois variety, this being the variety which appeared to suffer the most in yield as the result of infestation during 1936.

On the other hand, the Pritchard variety, used only in 1936, showed an increase in the per acre value of fruits from

Table 11.—Per acre value of marketable fruits of U. S. no. 1 and no. 2 canning grades in dollars and cents.

Variety	Year	Free of Nematode			Infested with Nematode			Loss or Gain in Per Acre Value
		Value of No. 1 Grade	Value of No. 2 Grade	Total	Value of No. 1 Grade	Value of No. 2 Grade	Total	
Baltimore	1936	105.82	42.08	147.90	90.50	41.02	131.02	+16.38
Pride of Illinois	1936	110.94	47.70	158.64	80.93	45.70	126.65	+32.01
Marglobe	1936	90.98	30.51	121.49	81.87	20.23	102.10	+19.39
Pritchard	1936	126.99	36.27	163.26	134.64	35.52	170.16	− 6.90
Baltimore	1937	79.80	31.50	111.30	66.36	25.20	91.56	+19.74
Marglobe	1937	65.20	26.04	91.56	55.20	17.36	72.56	+19.00
Baltimore*	1937	72.48	27.58	100.06				

* Home-grown plants.

the infested plots when graded as canning tomatoes. The total yield of all classes of fruits of this variety was lower in both number and weight in the infested than in the free plots but an increase in the yield of grade no. 1 canning fruits put the infested plots ahead of the free in the value of salable ripe fruit of canning grade. This variety was very seriously infected with early blight and severely infested with nematode. This resulted in earlier and more nearly complete defoliation of the infested plants of this variety than of any of the other varieties. The per acre value of the marketable grades of the four varieties grown in 1936 was $15.88 per acre less for the infested than for the uninfested plants.

In spite of the differences in total yields between the Baltimore and Marglobe varieties grown in 1937, the per acre difference in the value of the marketable fruits from infested and free plants was about equal, table 11, and amounted to an average to $19.37 per acre.

It was thus evident in these experiments that the profits on canning tomatoes were considerably reduced either directly or indirectly by the presence of nematode infestation in plants originating in the South and used in the experiments for the production of tomatoes of canning grades.

OVERWINTERING OF NEMATODE AT AUBURN.—Overwintering experiments consisted of the planting of nematode-free tomato plants in concentrated burials of infested roots made in the fall of 1936 and in the plots where infested plants were grown during the previous season. The concentrated burials were put in at depths of 6, 12, 18 and 24 inches. Free plants were grown over these burials during 1937, and 500 plants were planted in soil where infested plants were grown during 1936. In no instance did any of these plants become infested. It therefore seems improbable that the nematode wintered over out-of-doors in this locality, in spite of the mild winter of 1936–1937.

SUMMARY.—Two years of work with tomato plants originating in the South in which plants free of root nematodes were compared with infested plants, indicate some effects of nematode infestation on tomato yields which have a direct bearing on the production of canning tomatoes.

During the drought year of 1936, there were indications that the number of plants which failed to survive setting was increased by nematode infestation. Where infested plants were used additional resetting was necessary in order to produce full stands.

A decrease in the number of fruits set was evident in the infested plants of all the varieties studied during both seasons. The decreased size of the plants and their unthrifty condition during the early part of the season when the blossoming and the setting of the fruit occurred was probably responsible for this condition.

The number of fruits per acre which ripened and were harvested was greater on the free plants of all varieties during the two seasons than on the same varieties which were infested with nematodes. The percentage of the set fruits which ripened, however, was greater on the infested plants during the 1936 season, but in 1937 a slight reversal of this condition occurred. The plants were, however, less severely infested in 1937 than in 1936 and premature death and defoliation did not occur to the same extent.

The size of the fruits of marketable grades was decreased by nematode infestation in practically all instances. The size of the no. 2 grade of Pritchard during 1936 was the only exception to this condition. With the exception of the Marglobe variety in 1937, the average size of all grades as determined by weight was greater on the nematode-free plants than on the infested plants in all varieties during both years. While the decrease in the size of fruits does not detract from the value of the tomatoes from the point of view of most of the canning industry, it doubtless has an effect on yield.

The yield of fruits of marketable grades was decreased by infestation during both years, with the exception of the Pritchard variety in 1936. Premature defoliation due to premature death of the plants as a result of nematode infestation and early blight was probably responsible for this condition. Early blight appeared to be more severe in infested plants than in plants free from nematode.

Since the yields of marketable fruit were reduced, the per acre value of the crop was also reduced by the presence of root knot nematode infestation. Yields were probably also diminished indirectly

as well as directly by the increased prevalence of disease in the infested plots.

One year of experiment to determine the possibility of the nematodes passing the winter out-of-doors in the northern part of Indiana indicated that they are probably not capable of surviving the winter in the locality concerned.—1-7-38.

Notes on the European Pine Shoot Moth in Connecticut

R. B. FRIEND, G. H. PLUMB and H. W. HICOCK
Connecticut Agricultural Experiment Station, New Haven

The European pine shoot moth, *Rhyacionia buoliana* (Schiff.), has been a serious pest of forest plantations of red pine in Connecticut for a number of years. Its biology, distribution, and host plants are well known and have been discussed in many publications. The principal injury caused by the insect is that of boring into buds in the fall and into developing shoots in the spring. The death of buds and shoots leads to the development of latent buds just below the tip of the twig with a consequent bushy type of growth. When the infestation is severe, terminal growth is inhibited and, because little new growth survives to produce needles, a progressive defoliation of the tree may take place. If the attacked growing shoot is not killed, it becomes badly distorted, and, if this occurs on the terminal shoot of the tree, the main stem becomes permanently curved. This is the so-called "posthorn" or "bayonet."

In the course of their investigations of the relations of this insect to the development of red pine stands, the authors have obtained certain information about its population and the effect of this population on the trees. In addition to this, notes on the occurrence of some of the insect parasites of the pine shoot moth and on the status of the pest are included in this paper.

The authors take this opportunity to acknowledge aid given by Philip Marvin, W. W. McCartney and A. DeCaprio, all of whom have worked on some phase of the pine shoot moth problem and without whose assistance much of the information given here could not have been obtained.

Table 1.—Distribution of infestation of the European pine shoot moth on red pine, by whorls.

	Plantation					
	A	B	C	D	E	F
Average height of trees	5.4 ft.	6.6 ft.	7.2 ft.	25.0 ft.	6.3 ft.	8.4 ft.
Trees sampled	10	10	10	5	10	10
Injured tips per tree	199±19	102±9	148±12	91±14	13.3±1.9	6.3±1.8
Per cent of terminals injured*	100	90	90	100	60	30
Laterals injured						
First whorl	100	94	83	79	33	14
Second whorl	89	72	72	81	20	5
Third whorl	83	52	41	51	16	2
Fourth whorl	86	50	43	49	15	3
Fifth whorl	80	37	48	36	8	3
Sixth whorl	76	22	40	19	2	2
Seventh whorl	64	27	32	8	1	2
Eighth whorl	94	22	16	4	—	5
Ninth whorl	95	—	18	0	—	—
Tenth whorl	90	—	—	—	—	—

* An injured tip is one on which the buds or new shoots are bored by larvae.

DISTRIBUTION ON TREES.—The larval population of the pine shoot moth is concentrated on the tops of the trees, an advantage to the insect but a factor which accentuates the injury caused. Friend & West (1933) gave the distribution of injured tips on red pines about six feet high in pure and mixed stands. In the pure

stand the proportion of injured tips dropped regularly from 77 per cent of the terminals to 6 per cent on the branches nearest the ground (seventh whorl). Similar conditions occurred in the mixed stand. That this is a general feature of the infestation on forest trees of all heights up to about 25 feet, at least, is shown by the data in table 1. This is due to the oviposition habits of the adults and not to the migration of larvae. In Plantation A the increased proportion of injured tips on the lower three whorls of branches is due to the relatively few branches on these whorls. The same is true of the eighth whorl in Plantation F. Plantations since the proportion of leading to lateral shoots decreases as the tree grows, the chances for a leading shoot to be attacked are less in older trees, does not hold in the case of red pine in this state. Brooks believed that the number of eggs laid on twigs is directly proportional to the area of attractive green bark, but our observations indicate that this factor alone is not responsible for the location of larvae on the tree. It is quite true that after a certain stage of development is attained the shoot moth population in forest stands declines with increasing height of the trees, but no good explanation of this has been suggested. The larvae are more

Table 2.—Living larvae of European pine shoot moth per infested tip of red pine.

	PLANTATION				
	A	C	D	E	F
Number of trees sampled	10.0	5.0	5.0	10.0	10.0
Number of tips sampled per tree	39.0	46.0	45.0	13.0	6.0
Terminals (larvae per tip)	10.3	3.0	3.1	1.8	1.0
Laterals (larvae per tip)					
First whorl	3.8	1.5	1.2	1.0	.4
Second whorl	3.9	1.4	1.2	0.8	0.5
Third whorl	1.9	1.0	1.0	0.4	0.4
Fourth whorl	1.2	1.0	1.0	0.4	0.2
Fifth whorl	1.0	0.9	0.8	1.0	0.6
Sixth whorl	1.1	0.4	0.8	0.0	0.4
Seventh whorl	0.9	0.6	1.0	0.0	0.5
Eighth whorl	1.0	0.4	0.5	—	0.5
Ninth whorl	—	0.3	—	—	—
Total larvae per tree	*327*	*133*	*83*	*10*	*3*

E and F were lightly infested, B, C and D were fairly heavily infested and A was very heavily infested. Neither the height of the trees (up to the highest observed by the authors, about 25 feet) nor the intensity of the infestation in forest stands affects the general tendency of the moths to lay eggs in the tops of the trees. These observations were made in the fall, except in Plantation A, which was examined between February 2 and April 8, in stands where the trees were planted five or six feet apart and not thinned.

The relative abundance of larvae in the tips shows the same phenomenon, the number of larvae per infested tip being greater in the higher branches. This is shown by the data in table 2. All stands were examined in the fall except Plantation A, as mentioned before. The contention of Brooks & Brown (1936) who investigated the pine shoot moth in Scotch and Corsican pine stands in England, that abundant in the tops of trees regardless of the height (up to the limit attained by the trees examined, 25 feet). When trees grow in the open and are not crowded, then a greater proportion of the tips on the lower branches becomes infested, but the trend of the distribution does not change.

INJURY TO THE TREES.—The concentration of larvae on the upper branches has a certain survival value to the insect and enables a relatively small population to injure the tree. If the buds are large enough, usually one larva bores into one bud in the fall and one shoot in the spring. The presence of only one bud on a tip means that during its life the larva must either migrate or starve, and, if it migrates, it is exposed to additional environmental hazards. If the buds are so small that one will not sustain a larva during the fall feeding period, then the larva must migrate at least twice. On the lower

branches of red pine the buds are fewer and smaller than on the upper branches; hence the probability of larval survival should be less if the eggs were laid on the lower parts of the tree. The relative scarcity of infested tips on the lower branches, particularly tips bearing but one bud each, and the low number of larvae found per infested tip in the fall indicate that such a differential mortality is insignificant in its effect on the total population.

The fate of the buds on the terminals and upper five whorls of branches, on at a level of about 13 feet above ground (about the seventh whorl), shows the same trend as the other heavily infested stands.

In A and G the effect of a severe shoot moth attack is shown by both the number of buds produced on the terminals and the relatively small number of uninjured shoots which developed on the infested tips on all whorls of branches. Latent buds, a consequence of severe injury, were abundant on the terminals The whorls of lateral branches did not produce an aver-

Table 3.—Total injury to buds and shoots by European pine shoot moth.

	Plantation							
	A		D		E		G	
Average height	5.4 ft.		25.0 ft.		6.3 ft.		5.9 ft.	
Number of trees sampled	10		5		5		5	
Number of tips examined	389		227		28		148	
	Total buds produced per tip	Uninjured shoots per tip	Total buds produced per tip	Uninjured shoots per tip	Total buds produced per tip	Uninjured shoots per tip	Total buds produced per tip	Uninjured shoots per tip
Terminals	23.3	4.5	5.1	1.8	7.3	3.3	10.2	1.0
Laterals								
First whorl	5.7	0.0	2.8	0.4	6.0	3.5	4.7	0.8
Second whorl	7.0	0.0	2.1	0.8	4.5	2.0	2.7	0.5
Third whorl	4.7	0.7	1.6	1.4	2.9	0.6	1.5	0.4
Fourth whorl	3.2	0.5	1.7	0.6	3.9	1.1	1.4	0.3
Fifth whorl	3.1	0.4	1.2	0.5	3.0	2.0	1.4	0.5

which most of the larvae are found and which are very important to the growth of the tree, shows the injuriousness of this insect. In table 3 the number of uninjured shoots produced per tip in the spring is compared to the total number of buds found on these tips the previous fall. Plantation G was very heavily infested in the fall. The other plantations are the same as those in tables 1 and 2.

The data for Plantation E show about the normal number of buds on tips attacked by the insect when the injury is not sufficiently severe to cause latent buds to develop. The large number of buds on the tips of the fourth and fifth whorls is good evidence that the terminal tips of these branches are preferred by the insect. This coincides with the observations of Butovitsch (1936) on Scotch pine in Sweden. The average number of buds per lateral tip on these branches is about one on trees of this size.

Plantation D, in which the trees were about 25 feet high and which had closed

age of one healthy shoot per spring-infested tip. These figures show clearly why lateral branches are frequently missing from the upper parts of infested trees and why the tops of these trees become bushy and the terminals sometimes die. The trees in A and G have been so severely injured and are so heavily infested that the production of a merchantable crop of timber appears impossible without control measures.

There is a heavy larval mortality during the winter even when sub-zero temperatures do not occur, and this reduces the number of infested tips per tree in the spring as compared to the fall, especially in lightly infested stands. In all plantations mentioned in table 3, except A, the two columns are not comparable in regard to the total injury to the trees. The data for A were obtained between February 8 and April 2, 1937, after the greater part of the winter mortality had been effected (West 1936); so the number of infested tips in May would be about the same as

at the time of examination. In Plantation G, which was likewise severely injured, the total number of infested tips per tree was 54.6 in the fall and 45 in the spring, not a great decrease. On the branches down to and including the fourth whorl there were 43.1 infested tips per tree in the fall and 42.2 in May. This may be compared to conditions in plantation E in which there were 11.1 infested tips per tree in the fall and 4.6 on May 25 on all branches down to and including the fourth whorl. The larval mortality which normally occurs during the winter is more effective in reducing spring injury on the less heavily infested than on the more heavily infested trees because of the relatively smaller number of larvae present on the former.

The effect on the larval population of the destruction of a large number of buds is indicated by the data given in the tables for Plantation A, where 81 per cent of all the tips was injured and where there were 1.6 living larvae per tip over the entire tree. On the terminals and upper five whorls of branches there would be produced in the spring about 184 shoots, and there were 327 larvae per tree. If we assume an emergence of about 150 females per tree, then there would be less than two shoots per female, and many of these females would be weak because they developed from latent buds. The population of larvae on these trees could not increase much beyond the present level under any circumstances.

According to Butovitsch (1936) and Parr (1937), one of the reasons for the absence of severe injury to tall Scotch pine trees in Sweden was due to the small size of the buds and shoots and to the small number of buds per tip. In a 100-year old tree the larvae could not find sufficient food in the fall on one tip, and the spring shoots were not large enough to contain a fully grown larva. This means migration for food and shelter, with its attending danger. In red pine plantations in Connecticut the injury due to shoot moth attack declines after the stand closes, yet the buds and shoots are large enough and sufficiently abundant to support larval development. In Plantation D, which is still fairly heavily infested, the trees show much less injury than in 1932. According to Friend & West (1933), in the fall of 1932 about 70 per cent of the trees showed no terminal growth for the season. When examined in the fall of 1937, not 1 per cent of the trees in this part of the stand showed this condition, although many had some lateral branches missing from the first whorl.

Table 4.—Living larvae and pupae of European pine shoot moth per tree.

	Plantation								
	D			E		G		H	
	June 1936	Fall 1936	June 1937	Fall 1936	May 1937	Fall 1936	May 1937	June 1936	Fall 1936
Number of larvae per tree	24	83	27	9.7	4.2	54.7	40	48	69
Trees sampled	3	5	5	10	10	10	10	10	10

POPULATION IN FOREST PLANTATIONS.—The number of adults which emerge per tree gives some indication of the population densities and also, when compared to the number of eggs and larvae, of the effect of mortality factors. The number of mature larvae and pupae found in May or early June is a good criterion of adult emergence, since the mortality of late larval and pupal stages has been low up to the present. The only exception is in Plantation D, where the parasitism by *Orgilus obscurator* and *Cremastus interruptor* became significant in 1937, but this has been discounted in the estimations. The data for four plantations are included in table 4. In obtaining these figures, all tips in Plantation D which were injured in the spring and showed evidence that adults had already emerged were included.

Plantation G showed the first visible shoot moth injury to have occurred in 1932, and E in 1930. In G the nature of the injury showed a heavy infestation in 1936. In D the population did not increase significantly from the 1935 brood to the 1936 brood, and the evidence that the

shoot moth injury has declined here in recent years is indicated in table 4. The number of larvae present in the fall of 1936 is small compared with the number of adults which emerged in the spring of that year. One adult female could have been responsible, barring egg and early larval mortality, for more larvae than were found on any one tree in the fall. As many as 25 adults emerging per tree, regardless of tree size, indicates a fairly heavy infestation and subsequent severe injury.

In Plantation H, in which the trees were about seven feet high in 1936 and were obviously badly injured, 48 larvae per tree matured in the spring of 1936, and on September 1 of that year there was an estimated population of 69 larvae per tree. An increase in population of only about 50 per cent is not very great, and the saturation point was by no means reached, as the data in table 3 show.

The reproductive power of the female moths in the field is difficult to determine. Brooks (1936) made an estimate of 76 progeny per female. Friend & West (1933) obtained an average of 74.5 eggs per female in the laboratory. During the last season a much higher number of eggs per female was secured in glass cages in a shaded outdoor insectary. Ten females laid an average of 134 ± 12.5 eggs each and each had remaining in the ovarioles, after oviposition ceased, 182 ± 17 partly developed eggs. The total number laid by any one female varied from 11 to 203. The number of eggs in the ovarioles was determined by counting the visible swellings in the intact organs, a procedure open to some criticism but nevertheless giving a fair estimate of the reproductive potential. The largest number of eggs found in any female before oviposition was 590, and five females from Plantation D averaged 373 ± 18 each.

That the rate of increase of the insect in a red pine stand is by no means so great as the potential reproductive power of the females is obvious. The difficulty of finding eggs on the trees and the long period during which moths are active make it difficult to determine how many eggs are deposited per tree. In Plantation D, at the height of the oviposition period, June 29, 1936, a sample of twigs gave an estimated number of 165 eggs per tree, probably not over 50 per cent of the total for the season. Even if this number is doubled it represents only the number produced by 2.5 females in the insectary, and 12 females emerged per tree.

Most of the information given on the shoot moth population refers to conditions where the insect is abundant. Field observations show that when conditions permit an outbreak to develop the initial increase of the population is rapid. Thus Friend & West (1933) recorded an increase on the lateral branches of from 1.8 infested tips per tree in June to 48.4 in September.

It appears that the shoot moth population increases rapidly in a stand during the first few seasons and then slows down, whether or not it attains a saturation point depending on the height of the trees. In three to five years after the first appearance of infested tips severe injury to the trees may occur. In Plantation D the first visible injury had occurred in 1927, and the trees were very severely attacked in 1931. In A the first visible injury had occurred in the fall of 1930 and the population had reached a saturation point six years later. In G the first visible injury had occurred in 1932 and the trees were badly damaged in the fall of 1936. The same was true in H. If the trees are of such height that the stand closes before any injury to the trees has taken place, then the shoot moth damage is usually negligible. However, if a fall population of between 50 and 80 larvae per tree is reached by the time the trees are six feet high, then damage to the trees may continue for some years after closure. This population will be sufficient to cause considerable injury to trees up to 25 feet in height, as the data given in the tables show. If the trees become infested the first year or two after setting, then the insect population may reach a saturation point before the trees become over six feet high, and the recovery of the stand appears remote. Such a trend is shown in Plantations A and G.

The determination of that period during the life of the insect when the environmental pressure is greatest represents some difficulties. There are no available data on the destruction of eggs. The small number of eggs found on the trees is doubtless due to the destruction of adult females before oviposition is completed

or even begun. Probably not over 20 per cent of the reproductive capacity of the moths is realized in eggs laid. The eggs are practically all fertile. In Plantation H a sample of one twig from each whorl, including the terminal, of 10 trees in July, 1937, showed 395 bored needle clusters, 36 bored buds, 108 living larvae and 52 dead larvae. About one-third of the larvae found were dead at this early date. A similar examination of five trees in D the last of July and the first of August, 1937, showed 158 bored needle clusters, 7 bored buds, 24 living larvae and 2 dead larvae. The small number of living larvae compared to the large number of bored needle clusters shows a high larval mortality. In table 4 the data show a winter mortality in 1936–37, when the lowest temperature attained was about 6 degrees F., of 27 to 67 per cent. After the middle of May, when the larvae become fully grown and begin to pupate, the mortality has been insignificant except as noted in a later paragraph where the parasite *Orgilus obscurator* is abundant. The operation of mortality factors has been severe for all stages up to fully grown larvae, and insect parasites appear to have played a very minor role in this to date. The successful establishment of parasites or predators which would depress the larval population even a relatively small amount, in addition to the effect of the present environment, is highly desirable.

INSECT PARASITES.—The shoot moth parasite most commonly found in Connecticut is the Eulophid, *Hyssopus thymus* Gir. This insect feeds gregariously and externally on the host larva of all stages. It hibernates in the host burrow as a pupa and has several generations a year. In the laboratory constant temperature room, held at 24 degrees C., and 60 per cent relative humidity, the total period of development from egg to adult was 17 to 18 days. Under the same conditions and with moist sugar available as food, several adult females lived five weeks. Field observations also indicate several generations. Pupae and adults have been collected in May and during the summer, eggs and larvae in July and August, and pupae throughout the winter. Apparently the parasite can exist on the shoot moth alone, although it has other hosts. Adult females have been found more commonly than males. From miscellaneous field collections, 16 females and 7 males were reared, and 15 adults reared in the laboratory were all females.

The abundance of *H. thymus* was determined between the fall of 1936 and the spring of 1937 by Mr. Marvin in red pine stands in Fairfield County. In five plantations the proportion of injured tips containing the parasite varied from 2.0 to 3.8 per cent. In two other plantations which were very lightly infested 19 per cent of the injured tips contained parasites, one of these having a total of 27 living shoot moth larvae and 39 parasite pupae on 10 trees. The parasite is not, however, considered solely responsible for the light shoot moth infestation. In Plantation A, 5.8 per cent of the injured tips contained parasites and, in C, 2.6 per cent. The average number of *H. thymus* pupae per bud containing them in 1607 tips examined was 3. The protection afforded the host larvae when in their burrows may be partly responsible for the inability of this parasite to increase more rapidly in heavily infested stands. Another factor may be the long period in June and July when few if any host larvae are available.

The internal larval parasites of the shoot moth have not been abundant to date. Mr. Marvin dissected 600 hibernating larvae and found nothing. In Plantation D, the United States Bureau of Entomology and Plant Quarantine liberated two European parasites, *Orgilus obscurator* Nees. and *Cremastus interruptor* Grav., in 1932. A number of infested tips collected here on June 12, 1937, contained 113 living larvae and pupae. From the larvae 15 female and 1 male of *Orgilus*, 3 males of *Cremastus* and 4 cocoons of one species or the other were obtained. This appears very promising.

PRESENT STATUS AND CONTROL OPERATIONS.—The status of the pine shoot moth infestation in Connecticut up to 1933 has been reported by Friend & Hicock (1933), but since then some additional information has been acquired. The southwestern part of the state, Fairfield County, continues to be the most generally infested area. Thirty per cent of the 11 plantations examined in 1933 had a heavy or medium infestation, that is, the trees were visibly injured, and 70 per cent had a light or no infestation. A more comprehensive survey in 1934 covered 152 plantations, of which 39 per

cent had a heavy or medium infestation and 61 per cent a light or no infestation. This condition prevailed through 1935 and 1936, but in 1937 193 plantations were examined and in 50 per cent the infestation was medium to heavy. The trees in these stands run up to about 15 feet in height.

In the remainder of the state the injury is not so prevalent. In New Haven County, just east of Fairfield, a medium to heavy infestation was found on 37 per cent of the 46 plantations examined in 1933, 14 per cent of 59 plantations in 1934, 19 per cent of 140 plantations in 1935, 15 per cent of 112 plantations in 1936 and 28 per cent of 58 plantations in 1937. In the other two counties, Middlesex and New London, bordering Long Island Sound, the infestation was medium to heavy in 7 to 8 per cent of the stands and had decreased noticeably since 1933. In the northwestern part of the state, Litchfield County, 4 per cent of 75 plantations were infested to the same degree in 1936, and like conditions prevailed the same year in Hartford County, east of Litchfield, in 13 per cent of 31 stands. If the southern parts of these two counties were eliminated, the proportion would be much lower. In 1933 the percentages were 22 for Litchfield and 26 for Hartford. In Tolland and Windham counties, comprising the northern part of the state east of the Connecticut River, the insect has never been abundant. In 1933, 9 per cent of 158 stands had a medium infestation, and in 1934 this dropped to 1 per cent due to the previous cold winter. One stand out of 19 examined had a medium infestation in 1935, none in 1936; and, of the 85 stands examined in 1937, one was heavily infested, 90 per cent of them being apparently free of the insect. The low population of the insect in the northern part of the state is attributed to low winter temperatures (West 1936).

The relative abundance of the shoot moth has affected the control operations in different parts of the state. The efficiency of these operations depends on keeping the insect out of the plantations or at least at a low population level until the stands close. The generally heavy infestation in Fairfield County, on ornamental trees as well as in forest stands, not only has made it difficult to reduce the insect population in any one area but also has made reinfestation within a short time probable. More attention has therefore been devoted to other parts of the state. In the northern towns the possibility of a severe infestation building up is not very great. The stands in this region are examined each year by an arrangement with the Civilian Conservation Corps, and only those in which the population is reaching a danger point are treated by control crews. In the towns along Long Island Sound the control crews organized under Federal relief agencies do as much work as the number of available men permits.

The total amount of shoot moth control work over the state as a whole is shown in table 5. The control operations have had an appreciable result in many areas and the stands are coming through in good condition. The reason for the increase in the proportion of heavily infested stands in 1937 in New Haven County lies in the concentration of effort on plantations where the insect population was building up to a dangerous level. This is a logical procedure in any large control operations being carried out against any forest insect of this kind.

Table 5.—Summary of control operations of European pine shoot moth in Connecticut.

Brood	Number of Plantations	Total Acres
1933	933	11,917*
1934	871	11,244
1935	479	7,518†
1936	247	3,286‡

* Including 3500 acres worked twice.
† Including 245 acres worked twice.
‡ Including 191 acres worked twice.

Summary.—The larval population of the European pine shoot moth in red pine stands is concentrated in the tops of the trees. This is shown by the decrease in the proportion of tips attacked and in the number of larvae per tip from the terminal down to the lower whorls of branches. This tendency to attack the tips on the upper branches of the tree is advantageous to the larvae because of the more available supply of food in this part. At the same time it enables a small number of larvae to injure the tree seriously. In very heavily infested stands the injury may be so severe that the upper whorls of branches will not produce an average of one normal shoot each in the growing

season. The presence of 50 to 80 living larvae per tree in the fall, or the emergence of 25 adults in the spring, is a population of sufficient density to cause significant damage to the stand. This density may be reached in three to five years after a stand becomes infested. The population necessary to injure trees is the same for all trees from 6 to 25 feet in height. The shoot moth population increases rapidly at first, then more slowly. Whether or not a saturation point is reached depends much on the height of the trees. If the population is at a low level when the stand closes, injury to the trees is usually negligible. There is a heavy mortality of larvae of all stages up to the fully grown condition, and evidence points to a heavy adult mortality before the females lay all their eggs.

The most common larval parasite is *Hyssopus thymus* Gir., which attacks all stages found in buds and shoots. This parasite usually occurs in about 3 per cent of the injured tips, but in a few stands the proportion has been much higher. *Orgilus obscurator* Nees., an introduced European species, was found in significant numbers in one stand.—1-7-38.

LITERATURE CITED

Brooks, C. C., and J. M. B. Brown. 1936. Studies on the pine shoot moth (*Evetria buoliana* Schiff.). For. Com. Bul. **16.**

Butovitsch, V. 1936. Studier över Tallskottvecklaren, *Evetria buoliana* Schiff. Del. I. Med. fran Statens Skogsförsöksanstalt, Häfte **29.** N:v 5.

Friend, R. B., and H. W. Hicock. 1933. The status of the European pine shoot moth in Connecticut. JOUR. ECON. ENT. **26**(1):57–62.

Friend, R. B., and A. S. West, Jr. 1933. The European pine shoot moth. Yale Univ. Sch. For. Bul. **37.**

Parr, T. 1937. The European pine shoot moth in Sweden. Jour. For. **35:** 269–73.

West, Jr., A. S. 1936. Winter mortality of larvae of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.), in Connecticut. Ann. Ent. Soc. Amer. **29:** 438–48.

Insecticides Applied by Autogiro to Control Cankerworms Infesting Forested Areas

CLYDE C. HAMILTON, *New Jersey Agricultural Experiment Station, New Brunswick**

The control of leaf eating insects on foliage is ordinarily easily accomplished by arsenicals such as arsenate of lead. The cost of applying the arsenate of lead to wooded areas and forest trees by the usual methods of using high pressure ground sprayers has prevented its extended use as a liquid spray for the control of leaf eating insects. Dust applications of arsenate of lead or calcium arsenate have given good control of many insects but are objectionable in that the dust drifts excessively when there is any appreciable wind, and cannot be used in areas where food crops are grown or in heavily inhabited regions.

The development of apparatus, by Giro Associates, Inc., of Morristown, N. J., for applying concentrated water sprays from the air has made it possible to control cankerworms and other leaf eating insects attacking forest trees. This method of controlling cankerworms was first used by E. H. Francis (1936) of the United States National Park Service at Morristown, N. J., in the spring of 1936. The purpose of the tests reported in this paper is to determine the effectiveness of several different arsenical sprays and dusts in killing cankerworms infesting forested areas.

CANKERWORM INFESTATION, SPRING OF 1937.—Several species of cankerworms and other leaf eating caterpillars have been abundant in northern and central New Jersey the past several years. The fall cankerworm, *Alsophila pometaria* Harr.), the spring cankerworm, *Paleacrita vernata* (Peck), and the elm spanworm, *Ennomos subsignarius* (Hubn.), were the most abundant and caused severe injury to forest trees such as oaks, ash, hickory, elm and maple.

Several species of oak were weakened so

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

that many of the trees were attacked by borers and killed. The first females and egg masses of the spring cankerworm were found, March 5, on dogwood twigs forming the undergrowth in the woods near Bound Brook. Females of the fall cankerworm and the spring cankerworm were found as late as Arpil 3. The first larvae of both species were found on May 5 and by May 10 they were common but not abundant on the foliage of maple and ash forming the undergrowth in the woods near Bound Brook. At this time the largest caterpillars were not more than one-fourth inch long and were still in the first instar. The foliage of the undergrowth was fairly well developed with only the tips of the twigs showing any feeding injury. The foliage of the forest trees was just beginning to develop about May 5 and it was not until about May 10 that there was sufficient leaf surface to justify spraying with the autogiro. Because of unfavorable weather conditions the first spraying (a commercial job) was made on May 15. The larger caterpillars in sunny places were then about one-half inch long and were causing noticeable injury to the foliage. The rainy and windy weather during the next two weeks interfered rather seriously with the applications of the material at the time they should have been made.

COOPERATORS IN THE WORK.—The following organizations cooperated in the experimental work. The Union County Park Commission of Elizabeth, N. J., Giro Associates, Inc., of Morristown, N. J., Johns-Manville, Inc., of Manville, N. J., Sherwin-Williams Company of Bound Brook, N. J., and Dye-Col Products, Inc., of New York City, N. Y.

DATA ON TEST BLOCKS AND MATERIALS TESTED.—Each test block consisted of 10 acres approximately 250 feet wide and 1750 feet long, and contained various types of forest trees usually infested with cankerworms. It was originally planned to collect the dead larvae and the frass from each of the test blocks by using 25 trays, 1 yard square for each block. The collections were to have been made daily and were to be used in computing the efficiency of the materials tested. It was necessary, however, to change the method of taking the data due to the unevenness of the infestation in the different blocks and even in the same block. Therefore, the blocks were treated as originally planned; foliage was collected from the small trees forming the undergrowth, brought back to the laboratory and fed to caterpillars collected from untreated areas. The number of dead larvae and the amount of frass produced by the feeding of the larvae were recorded at the end of 48 hours and 96 hours.

The materials tested, together with date of application and other pertinent information for each block are as follows:

No. 1.—Check, no treatment.

No. 2.—Lead arsenate, 23 per cent; fish oil, 9 per cent; petroleum oil, 1 per cent; water, 67 per cent. Application, 10 gallons per acre, made May 26 at about 6 p.m.

No. 3.—The same materials and rate of application as used in block no. 2. Applied May 16 at about 4 p.m. Slightly windy; humidity low and as a result some water evaporated from the spray before settling on the foliage and spray did not adhere in a manner entirely satisfactory.

No. 4.—The same materials as used in no. 2, except that the rate of application was five gallons per acre. Applied May 28. Good distribution and smaller drop size than in blocks 2 and 3.

No. 5.—Calcium arsenate, 23 per cent; fish oil, 9 per cent; mineral oil, 1 per cent; water, 67 per cent. Application, 10 gallons per acre, made May 26 about 6 p.m. A distinct deposit of spray drops which did not appear to adhere as well as nos. 2 and 3.

No. 6.—A lead arsenate paste made by Sherwin-Williams Company, Bound Brook, N. J., by adding a dispersing agent to the lead arsenate. This was used at the rate of 4 pounds lead arsenate, dry basis, to 10 gallons of water per acre. Spray applied May 26 about 6:30 p.m. The spray came down in fine drops, giving a uniform and even particle distribution.

No. 7.—The same materials as used in no. 6 except that the material was used at the rate of 2 pounds of lead arsenate (dry basis) per acre in 10 gallons of water. Applied May 26 about 7 p.m. The spray came down in fine drops, giving a uniform even distribution.

No. 8.—*Led-ko* colloidal lead arsenate (manufactured by Dye-Col Products Company, Inc., of New York City, 55 per cent lead arsenate), used at the rate

of 2½ pounds of the paste (22 ounces dry lead arsenate) to 10 gallons of water per acre. Applied May 26 about 6 a.m. The spray came down as a wet spray, with very little drying out in the air. No noticeable discoloration or spotting of the foliage.

No. 9.—*Led-ko* colloidal lead arsenate as in no. 8 but used at the rate of 1¼ pounds (11 ounces dry lead arsenate) per acre in 10 gallons of water. The spray came down as a wet spray and did not leave any appreciable discoloration on the foliage.

No. 10.—In this block was used a dust consisting of lead arsenate, 53 per cent; *Celite* (a diatomaceous earth secured from Johns-Manville Inc., Manville, N. J.), 25 per cent; and a petroleum oil (about 70 viscosity and 90 per cent unsulfonatable residues) 22 per cent. After the lead arsenate and *Celite* were mixed together, the oil was added. The final mixture contained too much oil and as a result the dust was in fine hard pellets rather than a fluffy condition. Forty pounds of the dust were applied per acre, giving approximately 21 pounds of lead arsenate. The application was made May 28 about 6 a.m. Foliage was wet, resulting in the dust particles sticking to the leaves.

No. 11.—A dust mixture consisting of lead arsenate, *Celite* and petroleum oil in which the *Celite* was added to the batch in the process of precipitating the lead arsenate. This was dried, ground and the petroleum oil added. The final mixture consisted of 60 per cent lead arsenate, 25 per cent *Celite* and 15 per cent petroleum oil. The dust was applied at the rate of approximately 40 pounds per acre, giving 24 pounds of lead arsenate per acre. Application was made May 28 about 6:30 a.m. This dust mixture did not contain enough petroleum oil and some drifting occurred.

KILL CAUSED BY MATERIALS TESTED.—At the time of starting the laboratory tests the cankerworm larvae averaged about three-fourths to seven-eighths inch in length and were still feeding actively. However, in the laboratory tests many of the larvae discontinued feeding after eating a small portion of the foliage. They were not killed but gradually decreased in size and some of them changed to the prepupal stage but did not pupate.

The data on the kill of larvae at the end of 96 hours show that the highest kill was obtained where the greatest amount of lead arsenate was deposited on the foliage, table 1. For example, lot no. 2, sprayed May 26, gave a higher kill than no. 3, sprayed 10 days earlier. The date, as well as observations at the time of conducting the tests, show that the greater the quantity of lead arsenate on the foliage the quicker the kill. The kill was not high in any of the feeding tests, due, as previously stated, to the larvae discontinuing feeding before obtaining a lethal dose.

REDUCTION IN FEEDING CAUSED BY MATERIALS TESTED.—Because the larvae did not feed until a lethal dose had been consumed, it seemed that the better comparison of the materials in the test blocks was obtained by observing the reduction in the feeding as indicated by the quantity of frass produced. This data is given in table 2.

The data in table 2 show that there was a marked decrease in the amount of larval feeding in all the test blocks. The best block, no. 2, shows a reduction of 87.4, while the poorest block, no. 9 shows a reduction of 67.5 per cent. The reduction in the amount of feeding indicates a better control of the larvae than is shown by the percentage of dead larvae given in table 1. The differences in the efficiency of the different materials is not so great on the basis of the reduction in the feeding as on the number of larvae killed. It is the writer's opinion that the data presented in table 2 on the reduction in feeding more nearly expresses the comparative value of the materials than does the actual number of dead larvae as given in table 1. Observations made at the time of the tests showed that the larvae started to feed when first placed on the poisoned foliage, but soon discontinued feeding before obtaining sufficient poison to kill them during the 96-hour test period. This feeding reaction of the larvae presumably was caused by the larvae having nearly completed their growth.

OPTIMUM QUANTITIES OF ARSENATE.—The highest kill of the larvae and the greatest reduction in frass occurred in those blocks where the greatest quantity of lead arsenate or calcium arsenate adhered to the foliage, as noted in blocks 2, 3, 4, 5 and 10. This higher kill may have been due to the larvae getting sufficient

poison in a small amount of feeding to give a lethal dose. The somewhat lower kill in plot 3 as compared to plot 2 is apparently due to plot 3 having been sprayed May 16, or 10 days earlier than plot 2.

the mixtures or possibly to differences in humidities at the time of the spraying. In the commercial spraying done by Giro Associates, Inc., it was found necessary to increase the quantity of petroleum oil slightly with a decrease in the humidity.

Table 1.—Number and per cent of dead cankerworm larvae 96 hours after starting feeding tests. Average of four tests started May 28, 29, 31 and June 2.

Plot Number and Material	Total Number Worms	Number of Worms			Per Cent Dead
		Dead	Moribund	Active	
1. Check	388	25	15	345	6.4
2. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	482	296	58	128	61.4
3. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	449	152	52	245	32.8
4. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 5 gal. per acre, 67%	294	149	20	125	50.6
5. Calcium arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	440	205	26	209	46.6
6. Sherwin-Williams dispersed lead arsenate, 4 lbs. per acre in 10 gal. water.	446	73	33	340	16.7
7. Sherwin-Williams dispersed lead arsenate, 2 lbs. per acre in 10 gal. water.	427	95	52	280	22.2
8. *Led-ko* colloidal lead arsenate, 2½ lbs. paste (22 oz. dry) in 10 gal. water per acre	428	101	55	272	23.6
9. *Led-ko* colloidal lead arsenate, 1¼ lbs. paste (11 oz. dry) in 10 gal. water per acre.	440	72	39	327	16.2
10. Lead arsenate, 53% *Celite*, 25% Petroleum oil, 22% Mechanical mixture, 40 lbs. per acre.	448	200	31	217	44.6
11. Lead arsenate, 60% *Celite*, 25% Petroleum oil, 15% Precipitated *Celite* and lead arsenate mixture, 40 lbs. per acre.	431	163	15	254	37.8

There was no appreciable difference in the kill or the reduction in the amount of frass when calcium arsenate was substituted for lead arsenate, as shown by comparing plots 2 and 4. The calcium arsenate did not adhere to the foliage quite so well as the lead arsenate. This may have been due to the differences in

A reduction in the amount of lead arsenate to 10 pounds per acre, as shown in plot no. 4, did not materially reduce its effectiveness. With five gallons of spray going through the distributor on the autogiro, the speed of the distributing blades was increased and resulted in finer particles and better distribution than oc-

curred in plots 2, 3 and 5, where 10 gallons of spray were applied per acre. This test, as well as the results obtained in plots 6, 7, 8 and 9, indicates that good control might be secured with considerably less than 20 to 23 pounds of lead arsenate in 10 gallons of water per acre.

Plots 6 and 7, in which a dispersed arsenate of lead was used at the rate of 4 and 2 pounds, respectively, in 10 gallons of water per acre, did not give a high kill of the larvae but did compare favorably with higher quantities of lead arsenate in the reduction of feeding, as indicated by the amount of frass produced.

The so-called colloidal lead arsenate paste, *Led-ko*, used in plots 8 and 9 gave results comparable to those obtained in plots 6 and 7. Observations during the tests indicated that 2½ pounds of *Led-ko* (22 ounces lead arsenate, dry basis) would probably have given good kill if the tests had been conducted before the larvae had nearly reached the full grown stage. Those larvae indicated as alive were much more active where 1¼ pounds

Table 2.—The amount of larval feeding as indicated by the reduction in the amount of frass produced at end of 96 hours.

Plot Number and Material	Number of Larvae	Total Grams Frass	Grams of Frass Based on 400 Larvae	Per Cent Reduction in Frass Over Check
1. Check	388	3.7411	3.8562	0
2. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	482	.5825	.4834	87.4
3. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	449	.7802	.6950	82.2
4. Lead arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 5 gal. per acre, 67%	294	.4985	.6782	82.4
5. Calcium arsenate, 23% Fish oil, 9% Petroleum oil, 1% Water, 67%	440	.9281	.8185	78.1
6. Sherwin-Williams dispersed lead arsenate, 4 lbs. per acre in 10 gal. water.	446	1.0624	.9528	74.6
7. Sherwin-Williams dispersed lead arsenate, 2 lbs. per acre in 10 gal. water.	427	1.1283	1.0569	71.5
8. *Led-ko* colloidal lead arsenate, 2½ lbs. paste (22 oz. dry) in 10 gal. water per acre.	428	.9626	.8996	73.2
9. *Led-ko* colloidal lead arsenate, 1¼ lbs. paste (11 oz. dry) in 10 gal. water per acre.	440	1.8384	1.2603	67.5
10. Lead arsenate, 53% *Celite*, 25% Petroleum oil, 22% Mechanical mixture, 40 lbs. per acre.	448	.7147	.6381	83.4
11. Lead arsenate, 60% *Celite* 25% Petroleum oil, 15% Precipitated *Celite* and lead arsenate mixture, 40 lbs. per acre.	431	1.0372	.9625	75.7

of *Led-ko* were used per acre than in the plot sprayed with $2\frac{1}{2}$ pounds of *Led-ko* per acre.

The kill and reduction in frass obtained in plots 10 and 11, treated with lead arsenate, *Celite* and oil dust mixtures, were better than those obtained in the plots sprayed with small amounts of lead arsenate but not so good as where 10 to 20 pounds of lead arsenate per acre were applied in the spray mixture. Neither of the dusts used in these two plots was of as satisfactory a mechanical mixture as dust tested and reported on by Hamilton (1937). The mechanical difficulties in mixing about 800 pounds of each dust material were greater than in mixing laboratory samples. The dust used in plot no. 10 contained slightly more oil than was necessary to give the best physical properties as regards drifting and adherence, and the dust used in plot no. 11 did not contain enough oil to prevent some drifting. These difficulties could be worked out with further tests. The field tests showed considerable possibilities for development of the lead arsenate, *Celite* and oil dust mixture. No advantage was gained by adding the *Celite* to the lead arsenate during the process of precipitating the lead arsenate.

SUMMARY AND CONCLUSIONS.—The data obtained from the field tests show that the kill was proportional to the quantity of lead arsenate applied per acre. The reduction in feeding, as indicated by the amount of frass produced, was also proportional to the quantity of lead arsenate applied per acre.

Satisfactory commercial control of the cankerworms was obtained with a spray mixture consisting of approximately 23 per cent lead arsenate, 9 per cent fish oil, 1 per cent petroleum oil and 67 per cent water. The tests indicate, and it is the writer's opinion, that satisfactory commercial control of cankerworms could be obtained by reducing the amount of lead arsenate to 10 pounds per acre in either 10 or 5 gallons of water. Plot no. 4 indicated that 5 gallons of spray mixture per acre gave good coverage of the foliage and good control of the cankerworms. The writer's reasons for believing that the charge of lead arsenate can be reduced is that even 5 gallons of spray per acre gave good particle distribution. Further, if 10 pounds of lead are used in 10 gallons of water, any one of the particles of spray would have sufficient lead arsenate to kill the cankerworm which eats it.

In plots 6 and 7, where 4 and 2 pounds of dispersed lead arsenate, and plots 8 and 9 where $2\frac{1}{2}$ and $1\frac{1}{4}$ pounds of colloidal lead arsenate, *Led-ko*, were used in 10 gallons of water (without additional wetting or adhering agents) per acre, the spray particles were smaller and better distributed, came down wetter and appeared to give better adherence to the foliage than in the spray mixtures containing fish oil and petroleum oil as the sticking materials. It is indicated that the use of protective colloids to prevent flocculation of the lead arsenate particles and evaporation of the water from the concentrated spray would be the next step in improving the application of lead arsenate sprays when applied by autogiro.

The favorable results obtained from the tests with the lead arsenate, *Celite* and petroleum oil dust mixtures warrants further work along the line of controlling leaf eating insects on certain crops by dust application from the air. The proportions of lead arsenate, *Celite* and petroleum oil can be so regulated as to produce a dust which will not drift and which at the same time will adhere to the foliage. —1-7-38.

LITERATURE CITED

Francis, E. H. 1936. Distribution of arsenicals from the air. Proc. Nat. Shade Tree Conf. **12:** 168–81.
Hamilton, C. C. 1937. Adherence and rate of settling of lead arsenate dusts for autogiro and airplane application. JOUR. ECON. ENT. **30**(3):399–404.

WHITE-FRINGED BEETLE quarantine action was taken by the state of Louisiana on May 5 with reference to infestations at New Orleans, the regulated area comprising two parishes and part of a third. The state of Mississippi recently amended its quarantine relating to the weevil, owing to the finding of new infestations in that state. The present quarantine applies to areas in three counties.

Observations of Grasshopper Parasitism in 1937*

WILLIAM P. HAYES and J. D. DECOURSEY, *University of Illinois, Urbana*

During the summer of 1937 when grasshoppers were ravaging crops in the midwestern states, frequent reports, especially in news dispatches, emphasized the fact that parasites were playing an important role in reducing the numbers of grasshoppers. Several news items noted that "red chiggers" were "killing" grasshoppers, and reports from the more western plains states recorded the occurrence of the sarcophagid, *Sarcophaga kellyi* Ald., in great numbers and of considerable help in limiting the number of grasshoppers. With these reports in mind the writers spent some time during July and August and thereafter looking into the matter of parasitism of nymphs and adults in the vicinity of Urbana, Ill., and Indianapolis, Ind. No observations were made on egg parasitism.

FUNGOUS DISEASE.—As early as mid-July, grasshoppers were being brought in that were infested with fungous disease. Apparently these infestations were localized in certain fields. One infestation, the most extensive known to the writers, was located near LeRoy, Ill. From August until frost large numbers of fungus-infested grasshoppers could be observed in these fields. The junior author with the aid of Prof. N. E. Stevens, plant pathologist at the University of Illinois, determined this fungus as *Empusa grylli* Fr. which is the most common and widely spread fungus attacking grasshoppers. The species infested were mostly *Melanoplus differentialis* (Thos.), the differential grasshopper, and *Melanoplus femur-rubrum* (DeG.), the red-legged grasshopper. A count of 120 living adults of *M. differentialis* collected at Urbana, Ill., on October 11, showed 10 per cent of these to be infested with *E. grylli*.

TACHINIDAE.—Particular attention in these observations was directed toward a determination of the importance of dipterous parasites. Uvarov (1928) in his excellent summary of grasshopper parasitism has pointed out that there are but two families of Diptera, the Sarcophagidae and Tachinidae, of importance as parasites of adult grasshoppers. In his lists of species reported throughout the world it can be noted that there are but two species of Tachinidae recorded from North America infesting grasshoppers. In the United States *Acemyia dentata* Coq. has been recorded by Morgan (1901) as parasitizing *M. differentialis* and the same species is noted by Treherne & Buckell (1924) in British Columbia as infesting *Xanthippus neglectus* (Thos.) and *Chortophaga viridifasciata* (DeG.). The only other record of a tachinid in North America is that of *Euphorocera claripennis* Macq. infesting *M. differentialis* recorded by Morgan (1901). In all specimens of grasshoppers examined by us during the summer, only a single larva was found which bore an elongated terminal process. It has been doubtfully referred to this family.

SARCOPHAGIDAE.—[Curran (1934) now recognizes this family under the name Metopiidae.] According to Uvarov (1928, p. 124), the percentage of infestation of sarcophagids in grasshoppers is often very high and records of 100 per cent parasitism are not rare in the literature. In Uvarov's list of species of this family recorded from grasshoppers there are 15 species of the genus *Sarcophaga* listed from North America on the authority of Aldrich. A few of these are recorded with some doubt as to their authenticity. Of these only *S. kellyi* Ald. has been studied in any detail (Kelly 1914). This species attacks both nymphs and adults and deposits larvae on the body of the host while in flight (adults) or hopping (nymphs). It has been recorded from *M. mexicanus*, *M. differentialis*, *M. femur-rubrum*, *M. bivittatus*, *Schistocerca americana* and *Dissosteira longipennis*.

Examinations of nymphs up to July 9 revealed no parasitism by maggots but on this date an examination of 35 nymphs revealed 2 first instar sarcophagid larvae in 2 hoppers, or about 5 per cent parasitised. On August 3, 60 nymphs and adults were dissected without finding any larvae but by the next morning the remains of the dissected hoppers kept in a closed fruit jar yielded one small larva.

During the period from August 26 to September 9, the junior author, assisted

* Contribution No. 193 from the Entomological Laboratories of the University of Illinois.

by Dr. R. M. DeCoursey, collected in the vicinity of Indianapolis, Ind., a total of 1000 nymphs and adults most of which were *M. differentialis* and *M. femur-rubrum*. Of these, 925 were adults and 75 were nymphs. These were dissected for dipterous parasites. Among the total, 1000, only 22 were found to be infested with a total of 39 maggots, giving a total of only 2.2 per cent parasitism and an average of 1.8 maggots per infested grasshopper. Among the 925 adults examined, 18 were infested with 34 larvae, or a parasitism of only 1.9 per cent, and among the 75 nymphs only 4 were infested with 5 maggots, giving a parasitism of 5.3 per cent. Apparently parasitism by sarcophagids increases as the season progresses, for an examination of 50 adults from the vicinity of Urbana, Ill., on October 11 showed 10 hoppers infested with 14 maggots, or an increase to 20 per cent. Of the 14 maggots found, 2 were dead and blackened when revealed by dissection, showing that mortality occurs after entering the host.

Since some sarcophagid larvae are scavengers that readily attack weakened and dead grasshoppers and others are parasitic, confusion often rises when attempts are made to distinguish between these two habits. Likewise, so little is known taxonomically about sarcophagid larvae that only dissection and not rearing can be relied upon to determine the degrees of parasitism, and then specific determination is not possible unless the maggots can be reared. Since no reliable method of rearing these larvae is known an attempt was made to culture dissected maggots in live grasshoppers. To do this, larvae removed from their hosts or those that emerged from dying hoppers were used. A small incision was made in the suture on the pleuron between the meso- and metathorax of the grasshopper. Here the underlying muscles could be easily spread apart with a needle, and a sarcophagid larva was then inserted in the slit. The larva would apparently enter the body readily, after which the incision was closed over with warm paraffin. Colloidin was tried as a sealing medium but proved unsatisfactory in that it did not adhere well and would "bubble out," an action caused by air coming out of the grasshopper's body. Larvae also entered readily into incisions made in the region of the third abdominal segment. Grasshoppers thus infested lived but a few days and no larvae were reared to pupation, although they could be removed from dying individuals and transferred to a new host.

In the third instar and pupal stage the chief character for distinguishing sarcophagids from other muscoid flies is the absence of the so-called "button" on the spiracular plate (stigmal plate). This "button" is absent in some Oestridae, but these do not occur as parasites of insects so there can be no confusion. In those Oestridae in which it is present, the "button" is located on the inner edge of the spiracular plate near the middle or on the lower half. Sarcophagid larvae have the posterior spiracular plates located in the bottom of a deep cavity—the "posterior cavity"—and it is often necessary to cut into the cavity to see the spiracular plates. The edges of the "posterior cavity" are always provided with a series of tubercles. Some tachinid larvae have a "posterior cavity" but they may be distinguished by the presence of a "button" on the spiracular plate.

In view of the fact that sarcophagid larvae are more numerous in grasshoppers than tachinids, infestations can usually be considered as caused by sarcophagids. The three instars of most cyclorrhaphous larvae can usually be distinguished by the number of respiratory openings in the peritreme of the posterior spiracles. There is usually but one slitlike opening in the first instar, sometimes two, having faint inner margins with no distinct space between the slits; no distinct partitions occur in the slits. The second instar spiracle has two distinctly separate slits, and the third instar has three slits in each posterior spiracle. First instar sarcophagids in grasshoppers may be distinguished by the following combination of characters: muscoid in shape; a complete band of sclerotized spines on all of the segments except the first and last; the so-called hypopharyngeal skeleton has two lateral hooks that are devoid of denticles. The second instar has the dorsal arm (cornua) of this skeleton with a deep incision posteriorly.

News accounts of the abundance of *Sarcophaga kellyi* in the western states brought up the question of its occurrence in Illinois. There are no published records

showing its distribution east of the Mississippi River, but D. G. Hall of the Division of Insect Identification of the U. S. Bureau of Entomology and Plant Quarantine informed the writers through C. F. W. Muesebeck that this species occurs sparingly as far east as Ohio. In attempting to ascertain if *S. kellyi* was present at Urbana, a series of grasshoppers was collected alive and kept in tight glass containers. From these, 12 adult sarcophagids were reared. These were determined by Mr. Hall. He stated that nine specimens were *S. reversa* Ald. and three were *S. sinuata* Mg. Of the two species, only *S. sinuata* has been recorded as a parasitic form, having been reared by Kelly (1914) from *Melanoplus differentialis*.

EXTERNAL MITES.—These external mite parasites of grasshoppers are frequently observed because of their bright red color. The common species in America is *Eutrombidium locustarum* Walsh, which name is considered by some authorities to be a synonym of the European *E. trigonum* Herm. On the grasshopper it is known that the mites are immature and that they drop to the ground when fully engorged. They then transform to so-called nymphs. These nymphs (according to Uvarov 1928, p. 117) find the egg pods of grasshoppers, engorge on the eggs and then transform to the adult stage, in which condition they hibernate. Among 1000 grasshoppers examined between August 26 and September 29, there were found to be 173 hoppers infested with mites, a percentage of 17.3. Of these, 925 were adults, among which 161, or 18.4 per cent, carried mites; and 75 were nymphs, 12 of which, or 16 per cent, were infested. The 161 adult hoppers bore a total of 412 mites or an average of 2.5 mites per individual. The 12 infested nymphs had 24 mites or 2 mites per hopper. On October 11 a count of 50 adult hoppers showed no mites present so that by this time most, if not all of the mites, had deserted the host to enter the soil.

THREAD WORMS.—In the examination of nymphs and adults for dipterous parasites a number of nematode thread worms (Mermithidae) were encountered. During the period from August 26 to September 9, a total of 925 adults were examined. Of them, 129, or 13.9 per cent, were infested with these worms. In the same period, 75 nymphs examined showed 17 infested, or 22.6 per cent. A count of 50 adults on October 11 showed one individual (2 per cent) infested with two worms. Later in October all worms had left the bodies of their hosts. On the basis of both adult and nymphal infestation the earlier count showed a total of 14.6 per cent infested. Christie (1937) reported an average infestation of 12 per cent among 2500 grasshoppers counted in New England. In 42 of his collections the parasites were exclusively *Mermis subnigrescens* Cobb; 17 collections were made in which both *M. subnigrescens* and *Agamermis decaudata* Cobb, Steiner & Christie were present, and 6 collections showed only *A. decaudata*.

According to Uvarov (1928) the vast majority of records of Gordiaceae in grasshoppers must be referred to Mermithidae. All records of Gordiaceae in insects cited by him are European with the exception of an early American record by Leidy. Uvarov (1928, p. 132) writes, "I would draw the attention of entomologists, who may happen to find them, to the fact that it is absolutely useless and even misleading to record them under fancy specific names, as is usually done; in all cases a determination by a specialist must be obtained. The careful collection of material for systematic studies would be of great value, since the progress of our knowledge of these parasites is barred by the unsatisfactory condition of their classification." In a footnote this word of caution is found "In collecting Mermithidae it must be remembered that they leave the host when immature and therefore indeterminable; they must be kept in moist sand until mature, which may happen only after a long period of time (up to two years)."

According to Christie (1937, p. 353) the most common nematode parasites of grasshoppers in the United States are *Agamermis decaudata* and *Mermis subnigrescens*. Both belong to the family Mermithidae. The former is occasionally found in other insects and the latter appears to be strictly a parasite of grasshoppers. Christie found *M. subnigrescens* naturally infesting nine different species of Orthoptera including both Tettigonidae and Locustidae (Acrididae). The above cited work and a previous paper on *A. decaudata* (Christie 1936) give detailed

life history studies of these two parasites. In *A. decaudata*, eggs are laid in the soil and the young larvae crawl to plants where they seek grasshoppers and penetrate through the body wall. In *M. subnigrescens*, eggs are laid on plants and are swallowed by the grasshoppers in feeding; upon hatching, the larvae penetrate the walls of the alimentary canal.

Specimens of thread worms dissected from grasshoppers in these observations were sent to J. R. Christie of the Division of Nematology of the U. S. Bureau of Plant Industry. Since these were immature specimens dissected from the body cavities of grasshoppers it is difficult and sometimes impossible to determine them to species. Those that were determinable belonged to the genus *Mermis*, except one specimen, which was a *Hexamermis*. Mr. Christie stated in a letter that "the specimens designated *Mermis* sp. are without much doubt *Mermis subnigrescens*." He further stated, "We have not identified a sufficient amount of material from Illinois grasshoppers to indicate whether species of *Mermis* or *Agamermis* are most common. I would expect *Mermis subnigrescens* to be the predominating species and the material you submitted seems to indicate that this is the case. *Agamermis decaudata* is probably also present although your material did not include it."

SUMMARY.—Parasitism counts of various enemies of nymphal and adult grasshoppers were made in Illinois and Indiana during the summer of 1937.

The fungus, *Empusa grylli* Fr., apparently was the most effective natural enemy, killing off large numbers of adult grasshoppers. A late seasonal count of infestation by this fungus in living hoppers showed a 10 per cent infestation. Tachinid parasites were unimportant with only one questionable larva observed in the body of a host.

Sarcophagid parasitism was first noted on July 9 when a single hopper was found infested. A 2.2 per cent infestation was noted in late August and early September and by October 11 the percentage had increased to 20.

External parasitic red mites (*Eutrombidium locustarum*) were common on hoppers and an infestation of 17.3 per cent was counted in late August and September, and by October 11 all mites had deserted the hosts to continue development in the soil. Mermethid thread-worm parasitism in the August-September counts was 13.9 per cent in adults and 22.6 per cent in nymphs. The most common species observed was probably *Mermis subnigrescens*. By October 11, most of the thread-worms had left the hosts so that on that date only 2 per cent parasitism was noted. Structural characters to facilitate the recognition of sarcophagid larvae in grasshopper hosts were investigated.—1-7-38.

LITERATURE CITED

Christie, J. R. 1936. Life history of *Agamermis decaudata*, a nematode parasite of grasshoppers and other insects. Jour. Ag. Res. **52**: 161–98.

Christie, J. R. 1937. *Mermis subnigrescens*, a nematode parasite of grasshoppers. Jour. Ag. Res. **55**: 353–64.

Curran, C. H. 1934. The families and genera of North American Diptera. Ballou Press, New York. 512 pp.

Kelly, E. O. G. 1914. A new sarcophagid parasite of grasshoppers. Jour. Ag. Res. **2**: 435–46. 1 plate.

Morgan, H. A. 1901. The differential grasshopper in the Mississippi Delta. U.S.D.A. Div. of Ent., Bul. **30**, New Series, pp. 7–33, 19 figs.

Treherne, R. C., and E. R. Buckell 1924. Grasshoppers of British Columbia. Bul. Dept. Ag. Canada **39**. 40 pp., 18 figs., 3 plates.

Uvarov, B. P. 1928. Locusts and grasshoppers. Imperial Bur. Ent., London. 352 pp., 9 plates.

IN COMPLIANCE with the recommendations of the committee on standardization of state quarantines of the Southern Plant Board, the state of Alabama on May 11 revoked its quarantine relating to the potato tuber moth, retaining in effect rule 31 relating to various potato diseases.

IN CONSIDERATION of the extensive Federal campaign of eradication and control of the phony peach and peach mosaic diseases in the affected states, the state of Texas, on May 23, declared these diseases a public nuisance and ordered the destruction of all trees so affected.

Some Problems of the Annual Grasshopper Survey

ROBERT L. SHOTWELL, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

A method of making a grasshopper survey, which has since been quite generally adopted, was first described by the writer in the JOURNAL OF ECONOMIC ENTOMOLOGY for April, 1935 (Shotwell 1935). Since that time certain problems have developed in the course of making the surveys in the various states, and these the writer has discussed in open meetings and by correspondence with state agencies. Some of the more important of these problems are considered here, and the discussion which follows includes the combined ideas of many persons who have been working on the survey.

In the general survey three major subsurveys are included, *viz.* the nymphal, the adult and the egg surveys. In the spring a limited egg-survival survey is made previous to, but as a part of, the nymphal survey to determine the effect of drought, parasites and predators on the numbers of eggs. The nymphal survey is used as a check on the fall survey to improve the accuracy of predictions. The adult and egg surveys are the bases of qualitative and quantitative studies of grasshopper populations from year to year to determine the location and extent of prospective infestations the following year and to estimate the material needed for control.

When the grasshopper-survey method is explained to the average person for the first time he usually questions how anyone can determine with any degree of accuracy the extent of infestations in so large an area as a state or county with such a comparatively small number of stops (10 to 30 per county) for observation. There would be some justification for this question if the observations were made strictly at random, but as a matter of fact they are not so made. Years of study and research on the habits and activities of grasshoppers have shown where they are most likely to occur and that only places of these kinds need be examined to determine the extent of an infestation. Upon the chance of finding grasshoppers or their eggs in these places are based the predictions of the survey. Of course a greater number of stops in a county would increase the accuracy of the survey, but because of time and personnel it is possible to visit only a limited number of these most likely places. Therefore, 10 to 30 stops per county have been suggested as best meeting all conditions and requirements. By a selective random sampling in representative places in a county we are able, within the limits of feasible accuracy, to locate grasshopper infestations and determine their extent.

CLASSIFICATION OF INFESTATIONS.—Infestations are classified as follows: 1, normal; 2, light; 3, threatening; 4, severe; 5, very severe. Each of these classes was described in the writer's original article (1935), and the numerical ratings assigned are considered in determining the amount of control needed in any state or county. The different classifications were first described in terms of damage to crops, but the ratings are now used primarily to measure populations to determine the amount of control needed. In certain crops and under certain conditions a class 3 infestation with no control might eventually cause complete destruction, which is as much harm as a class 4 or class 5 infestation could do. These five ratings have often been wrongly assumed to represent damage to be expected, but crop damage is too variable a thing to be accurately predicted for any one type of infestation.

EVALUATION OF ACTIVE GRASSHOPPER POPULATIONS.—The evaluation of active grasshopper populations was first made to meet average conditions in the middle of September or about the beginning of the egg survey. This evaluation is based on the number of grasshoppers observed per square yard and was to aid in classifying concurrent egg populations.

A question has arisen regarding the difference between early-season and late-season counts of hoppers per unit and the effect this will have on the rating of infestations. When the grasshoppers first hatch they are concentrated for a time in small areas on the breeding grounds. Soon after hatching they begin to disperse and continue to do so until they again congregate for oviposition. During all this time natural mortality reduces their numbers gradually as the season progresses. While they are ovipositing, the numbers

of egg pods increase gradually until the last pods are deposited in the fall. During the summer there is also a constant shifting about of the grasshoppers, and in no field does the degree of infestation remain constant. Therefore no single evaluation based on the number of live grasshoppers or egg pods per unit area can fit all periods. Where active grasshoppers are considered, a different evaluation is necessary for the rating of populations during each of the three major periods of their distribution. These are as follows: The period during which the nymphs are concentrated, the period during which the adults are scattered, and the period during which the ovipositing adults are concentrated.

In all cases the size of the concentration must be considered in making the final rating. Also, two tabulations are necessary, one intended for use where large fields prevail and the other for use where small fields prevail (table 1). Furthermore, distinction is made between populations in the fields and populations along field margins, since usually there is a concentration along the edges of the fields.

EVALUATION IN THE EGG SURVEY.—In the egg survey (table 2) the numbers of pods are counted as so many per square foot in favorable egg-laying places. As in the survey of active grasshopper populations, a distinction is made between egg pods in the fields and those in the field margins, and between those in large and those in small fields.

DIFFERENCE BETWEEN LARGE AND SMALL FIELDS IN EVALUATION OF POPULATIONS.—In tables 1 and 2 a distinction is made between large and small fields. The tabulations for large fields are used in areas where fields average 40 acres or more in area, and the tabulations for small

Table 1.—Evaluations of grasshopper populations.

CLASSIFICATION		NUMBER OF ACTIVE GRASSHOPPERS PER SQUARE YARD DURING					
		Nymphal Concentration*		Adult Spread†		Oviposition Concentration*	
Name	Numerical Rating	Field	Edges	Field	Edges	Field	Edges
		Where Large Fields Prevail					
Normal	1.0	5	15	2	5	1.0	4
	1.5	7	23	3	7	1.5	6
Light	2.0	10	20	4	10	2.0	8
	2.5	15	50	6	15	3.0	12
Threatening	3.0	20	70	8	20	4.0	16
	3.5	30	110	12	30	6.0	24
Severe	4.0	40	150	16	40	8.0	32
	4.5	60	200	24	60	12.0	48
Very severe	5.0	80	250	32	80	16.0	64
		Where Small Fields Prevail					
Normal	1.0	7	10	4	5	2.0	3
	1.5	11	17	6	7	3.0	4
Light	2.0	15	25	8	10	4.0	6
	2.5	23	35	11	15	6.0	9
Threatening	3.0	30	50	15	20	8.0	12
	3.5	45	75	22	30	12.0	18
Severe	4.0	60	100	30	40	16.0	24
	4.5	90	150	45	60	24.0	36
Very severe	5.0	120	200	60	80	32.0	48

* Early in June. † In July and early in August. ‡ Early in September.

fields in areas where the average size of the fields is less than 40 acres. Farmland in the wheat areas of the Great Plains states is usually divided into large fields of 80 to 640 acres, each in a single crop. Favorable food conditions occur in large units, and a given summer population of adult grasshoppers on a section of land is spread over a wide area. Under a more diversified crop system and greater rainfall, a section of land is usually divided into fields of 5, 10 or 20 acres. Here a smaller proportion of the total crop area offers favorable food conditions for grasshoppers, and a correspondingly larger proportion presents unfavorable food conditions. As a result, the grasshopper populations are higher in the fields where they are concentrated, although the total number in the entire section is no greater and a higher rating is not warranted.

During the nymphal and oviposition periods, active grasshoppers are usually concentrated along field margins. There is proportionately less field margin in a section of land divided into large units than in one divided into smaller units. A given population along the margins during these periods is therefore likely to be more concentrated where the fields are large than it is where the fields are small. For the species that oviposit along field edges there is proportionately less area for egg deposition and a greater chance for the concentration of eggs under large-field conditions than under small-field conditions; hence higher counts are necessary to warrant a given rating where the fields are large than where they are small.

To allow for all these differences a given rating in the tables for evaluating grasshopper populations requires a greater number of active grasshoppers or egg pods within the fields and a smaller number along the edges if the fields are small than if the fields are large. No distinction is made between field margins of large and of small fields for the adult spread because the tendency to concentrate in the smaller units counterbalances any greater concentration along the edges of larger fields These rules are applied only in a general way and not to specific fields.

Table 2.—Evaluation of the grasshopper egg survey.

Classification		Number of Egg Pods Per Square Foot in			
		Large Fields		Small Fields	
Name	Numerical Rating	Field	Margin	Field	Margin
Normal	1.0	0.25	2	0.5	1.0
	1.5	0.37	3	0.7	2.0
Light	2.0	0.50	4	1.0	3.0
	2.5	0.75	6	1.5	4.5
Threatening	3.0	1.00	8	2.0	6.0
	3.5	1.50	12	3.0	9.0
Severe	4.0	2.00	16	4.0	12.0
	4.5	3.00	24	6.0	16.0
Very severe	5.0	4.00	32	8.0	24.0

THE NYMPHAL SURVEY.—Places visited in the fall egg survey are visited the following year during the nymphal survey to check on the accuracy of the prediction made the previous fall and to determine the current percentage of hatch. At the same time the relative abundance of species is also determined so far as possible. This survey has proved invaluable in control campaigns as a basis for directing the movement of bait materials where they will be needed first and most urgently. In two-weeks time, during the hatching period, the infestations in a state can easily be surveyed to determine the extent of hatching and the immediate needs for control. Valuable records are obtained in this survey by direct observations of the effect of weather conditions on the hatch and on the nymphs, and by observations of nymphal activities.

The rating of infestations during the nymphal survey is based on nymphal concentrations, as allocated in table 1, of active grasshoppers per square yard. Good judgment must be exercised in this matter because of the tendency to rate these concentrations too low when the young grasshoppers are too small to attract much attention. Actual estimates per square foot converted to a square-yard basis will give a more nearly accurate picture of the density of populations. On the other hand, small, dense concentrations of larger nymphs may cause a tendency to overrate an infestation unless the area of concentation is taken into consideration. Populations may be very dense along fence rows and in very small weed or grass patches, where eggs were concentrated in the fall, whereas a large proportion of the surrounding crop and land area may be entirely free of grasshoppers. All of these things must be considered in a nymphal survey.

THE ADULT SURVEY.—The adult survey is conducted to locate infestations and places where grasshoppers have congregated for egg deposition. Certain areas of little or no infestation are also located which later can be disregarded in the egg survey. Thus a general picture of conditions in a county or state is obtained which proves invaluable in making a good egg survey.

In order to be of real help the adult survey must be made late enough in the season to avoid the greater part of the error due to shifting adult populations. Stops for examination, evenly distributed over the farmed areas or areas of likely infestation, are usually made about 10 miles apart, several fields being covered at each stop. Estimates of numbers per square yard are made both in the field and along fence rows, roadsides and other places. Any other information of possible value is also recorded, particularly the location of females congregated for egg laying, the kind of crop or type of habitat in which the observation was made, and, so far as possible, the dominant and important species of grasshoppers in the order of their abundance. A rating is then determined for each stop, based on the number of adult grasshoppers per square yard as allocated in table 1, or, depending on local conditions, somewhere between the adult-spread and the oviposition-concentration allocations.

GRASSHOPPER COLLECTION.—In connection with the adult survey, special collecting areas are being chosen in locations close to weather recording stations. These areas are being located at vantage points throughout every state for the study of the fluctuations in grasshopper populations, both in numbers and in kinds, under representative agricultural, topographical and floral conditions, the areas extending some 10 to 15 miles about the weather station. The method of collecting and recording abundance is as follows.

Specimens of grasshoppers are collected from all typical environments in each area, collections being repeated in each habitat several times. These insects are killed by sousing the specimens, while still in the tip of the net, into a jar of radiator alcohol. Then they are spread out, dried and placed in packages suitable for shipping. With each collection a record is kept of the exact location, the numbers present per square yard and the environment where the collection was made. This record shows the kinds of crops or the dominant grasses and plants found in the habitat. All this information is essential for a study of this kind.

The environments usually selected for collections are (1) land in crops (small grain, legumes, corn, flax and miscellaneous); (2) grasslands (plain, or foothill, mountain, high mountain, native pasture, cultivated pasture, cutover or stump land); (3) bottomlands (along rivers and coulees); (4) roadsides (in native sod, often ungraded, and weedy, often graded); (5) weedy patches or waste lands; (6) idle lands (land idle from one to three years); and (7) abandoned lands (lands idle for four years or more).

THE EGG SURVEY.—In making a grasshopper-egg survey, as previously stated, the number of egg pods (not eggs) per square foot found in favorite breeding places is considered, whether these egg pods are scattered throughout the field or concentrated along the edges. When the egg survey is made, the adult grasshoppers are usually not all dead; and the numbers of these per square yard, both in the field and along the edge, are recorded and considered in rating a particular stop.

From the adult survey, and from the summer's observations and reports, certain areas of light or no infestation will have been recorded in each state. These areas need not be included in the egg survey. Observation stops are scattered somewhat uniformly over the areas of infestation and need not be so many per county as was the case in the adult survey. They should, however, be numerous enough to represent adequately the amount of egg deposition that has resulted from the infestation noted in the adult survey. In order to accomplish this, more time should be taken at each point of observation in order that every possible place for egg deposition may be examined. Each field will present a more or less different problem in the egg survey because of the many and varied conditions under which certain preferred spots for egg laying occur in different fields. There are also some differences among the species in their choice of spots, and this serves further to complicate the search.

The following four general methods of sampling for egg pods, each applicable to particular conditions, are in use:

A. Sifting.—A converted scoop shovel with the sides turned up and the blade sharpened is used to take a sample amounting to one-half square foot of surface 3 inches deep, 6 inches wide and 1 foot long, of a drill row of grain stubble or bare soil. Then the sample is sifted through a galvanized wire screen of about one-quarter-inch mesh after the roots of stubble, grass or weeds have first been examined and removed. The number of egg pods found in each sample is recorded as so many per square foot. This method is used in stubble fields and soil-blown fence rows.

B. Shaving.—The surface or bare soil is shaved with a small "razor-edged" car shovel or short mason's trowel until the tops of the egg pods are exposed. These can then be easily counted as so many per square foot. Sod containing egg pods can also be shaved, if the implement used is sharp enough, and a count made of the pods thus exposed. Ordinarily this method is used for bare spots in alfalfa fields, pastures and other places.

C. Sod Cutting.—Egg pods in sod can be counted by cutting out from one-fourth to 1 square foot of the sod to a depth of 3 inches and then separating the pods from among the roots. A sharp, stiff spade or shovel is needed for this. The pods are counted as so many per square foot or other size of sample. This method is used along field margins.

D. Single-Plant Digging and Pulling.—Plants with single rootstocks, such as sweetclover, corn stubble, sunflower and dandelion, often have egg pods laid alongside the rootstock or in the soil immediately surrounding it. Isolated clumps of bunchy grass, such as pigeon grass or foxtail, blue-stem and sand bur, also may have pods concentrated among their roots. There is usually bare, open ground between plants of the rootstock or bunchy-grass types. When these plants are pulled or dug, the pods may be found adhering to the roots or in the immediately adjacent soil. These pods are recorded as so many per clump pulled, or so many per square foot of area actually occupied by the plant.

SEARCHING FOR GRASSHOPPER EGGS.—Examinations for eggs are made both within and around the edges of fields because some species—*Melanoplus bivittatus* (Say), *M. differentialis* (Thos.) and *Camnula pellucida* (Scudd.)—tend to concentrate their pods along the edges whereas others—*M. mexicanus* (Sauss.), *M. femur-rubrum* (Deg.), *Ageneotettix deorum* (Scudd.) and *Aulocara elliotti* (Thos.)—scatter their pods throughout grain, alfalfa or grasslands. In both cases the more open plant cover is chosen for egg deposition and dense growth is avoided. The more exposed spots are selected, but not barren places. Egg pods are laid in the areas which remain greener during the egg-laying period. Stubble-fields with some green undergrowth are preferred to clean stubble. Stony or gravelly soil is avoided.

EGGS IN FIELD MARGINS (ROADSIDES, FENCE ROWS, HEADLANDS AND DITCH-BANKS).—The first six inches of the extremely soddy edges of cut banks facing southward are much preferred for oviposition by *M. bivittatus* and *M. differentialis*. Such banks facing eastward or westward may also contain pods. Grassy or weedy road banks facing southward are favorite places if not gravelly or loose in texture. Dry bottoms of roadside ditches often are selected if they contain

an open cover of clumps of grass or weeds. Ledges of washed dirt, below the edges of cut banks, form good places for *M. packardii* (Scudd.), *M. Mexicanus*, *M. femur-rubrum* and *Dissosteira carolina* (L.).

Single clumps of buffalo grass or other short grasses along fence rows or headlands are favorite places for *M. differentialis*, *M. bivittatus* or *Camnula pellucida*. Isolated clumps of taller grasses (pigeon grass) and plants with single rootstocks are good places for *M. differentialis* and *M. bivittatus*. Blown sand ridges form favorite spots for *M. mexicanus*, *M. packardii* and *D. carolina*. Weed patches (sweetclover, dandelions, sunflowers etc.) with open bare spots between plants form good egg-deposition places for *M. bivittatus*. *M. mexicanus* often concentrates its egg pods underneath Russian thistle plants. Edges of sod inside the fence row, left by the plow, also offer good egg-laying places, especially if the edges face southward. The more southern and western slopes of irrigation canals, ditches and laterals are favorite spots for egg deposition.

EGG COUNTS FOR FIELD EDGES.—All of the counts are started after several prospective samples have served in locating the egg bed. Each field may contain from four to a dozen different edges or ditchbanks where eggs may likely be found. The grasshoppers may select only one or two of these edges and still lay enough eggs to cause the area to be rated at 5. Therefore, a search for the spot or spots selected must be made first before the final count is started. Then from 10 to 20 samples are made along that edge or ditchbank and the counts are recorded as so many per square foot. If, after a reasonable search is made and few or no pods have been found, the count is based on the prospective samples.

EGGS IN THE FIELD.—In small-grain stubble, pods of *M. mexicanus* and other grasshoppers are to be found in the soil of the drill row and adhering to the roots of the stubble. The bare soil between alfalfa plants and the crowns of the same often contain egg pods of several species. Isolated clumps of grass and the bare spots between them contain the egg pods of species which frequent pastures and short-grass meadows. In stumpland pasture, pods of *M. mexicanus* have been found in the bare, packed soil between the projecting roots of the stumps and on the sides facing southward. Flat, half-buried stones in pastures often have heavy concentrations of egg pods of *M. differentialis*, *M. bivittatus* and *C. pellucida* in the sod immediately around them.

In any field, small ridges of sod, packed dirt or sand which may have been formed by a wheel rut, cultivation, wind or water may contain heavy concentrations of egg pods in their slopes or level tops. Grasshoppers often concentrate their eggs in the soil or stubble around a strawstack or haystack.

In check-rowed corn, where the soil is not loosely thrown up around the corn plant so as to bury the roots under several inches of loose soil, *M. bivittatus* and perhaps *M. differentialis* may deposit their eggs down along the stalk among the roots and in the packed soil immediately adjacent to the plant. In listed corn, where the soil is loosely thrown up around the plant, the pods are not likely to be deposited among the roots of the corn plant. If the listed corn has not been cultivated and the ground has become packed, the pods may be deposited in the stubble and along the ridge of the corn row. Soddy edges of cornfields are favorite places for *M. differentialis* and *M. bivittatus* because the corn is usually the last feeding place available to the grasshoppers during egg deposition. Clumps of grass in corn are favorable egg-laying places.

Fields containing other crops, such as flax, usually have about the same type of egg concentrations as those already mentioned.

Aulocara elliotti and *Ageneotettix deorum* lay their egg pods horizontally beneath the dry quarter-inch surface crust of bare, open, packed soil in pasture, grain or alfalfa fields. These are small, tough pods each containing about five or six pearly-white eggs. The pod of *A. deorum* is smaller than that of *A. elliotti*. These pods can best be dug by scratching them out with a special garden tool such as a small modified hand rake.

EGG COUNTS IN THE FIELD.—The egg pods found in the stubblefields are counted as so many per square foot of drill row, in samples one foot long by one-half foot wide. In alfalfa, flax, pasture, meadow or other fields the number of pods is recorded as so many per square

foot. Corn plants are pulled or dug and the pods counted from the roots and surrounding soil. Their number is recorded as so many per linear foot of drill row. In making field counts the proportionate area of good breeding places must be considered in the final evaluation of the infestation. This is discussed in the following paragraphs.

RATING INFESTATIONS—After the numbers of grasshoppers or egg pods or both per unit area have been determined for any given stop, a rating is given for that stop with the help of the evaluation tables. These ratings will range from 1 to 5, inclusive, decimal fractions being used for intermediate classifications. Certain conditions may induce the observer to bear away from the direct applications of the tables, and this is the correct procedure if rightly done. Certain problems which have developed in the course of evaluating infestations in the field will now be discussed.

A. Ratings Based on a Combination of the Number of Egg Pods and of Remaining Live Hoppers.—Suppose one should get a rating of 3, according to the evaluation table, on the number of live grasshoppers per square yard at the same time he gets a rating of 3 on the number of egg pods per square foot. Would he be justified in adding the two ratings together, thus making 6? Hardly, for there is no 6 rating. First, the field should be rated a 3 on the basis of the number of egg pods. Then, the question whether or not egg-laying is finished for the season must be considered. If additional oviposition is likely, the proper procedure would be to increase the rating to 3.5 or 4, depending on the time of the year the observation was made, the number of live grasshoppers remaining and their chances for laying more eggs. The number of egg pods the remaining females are likely to deposit and how much this would increase the egg-pod count per square foot would determine just how much the rating should be increased.

B. Size of the Egg-Laying Bed.—In rating certain fields one is often faced with the problem of considering not only the number of egg pods present per square foot but the size of the area containing these pods. *Melanoplus mexicanus* may oviposit in the bare ground between the plants in an alfalfa field. The greater the area of this bare ground in proportion to that bearing cover, the less concentrated will be the egg pods and the less will be the number per square foot for a given infestation. In a pasture of mixed weeds and sod, heavy concentrations of the pods of *M. differentialis* and *Camnula pellucida* may occur, depending on the locality. The greater the area of the sod in proportion to the rest of the field, the less will be the concentration of egg pods per square foot. When this problem presents itself, the observer must introduce a reduction factor by estimating what portion of the field is considered as good breeding ground and use this as a basis for reducing his count. By means of the evaluation tables he can use this reduced figure in determining the rating for the field. For example, a 40-acre pasture of mixed weeds and buffalo grass sod was rated in the 1935 survey. The sod contained egg pods of *M. differentialis* and formed about one-fourth of the total area of the field. Sample counts were made in the sod and expressed as averaging so many pods per square foot. This number was then divided by 4 and the result taken as so many pods per square foot in the field and rated accordingly. In cases of this kind, reduction factors must be introduced on the spot and mention made of the fact that they are being used.

C. Rating Mixed Populations of Species.—In the northern Great Plains area five species are usually considered of major importance. They are *M. mexicanus, M. bivittatus, M. differentialis, M. femur-rubrum* and *C. pellucida.* The egg-laying and other habits of these species vary and the numbers of eggs per pod differ considerably. In many places two or more of these species may be evenly mixed and in others one of them may outnumber all of the others. The evaluation tables were set up primarily to meet all these differences and to fit average conditions without the complication of an allocation for each species.

The assignment of numbers for the fields and field margins was made not so much with the idea of combining the two for determining a rating as of allowing for the egg-laying habits of the different species. For example, in South Dakota, where in some years *M. bivittatus* and *M. differentialis* are by far the most important species, the evaluations of the num-

bers of live grasshoppers and eggs found at the field margins on nonirrigated land are the best guides for determining the degree of infestation, because these species tend to congregate along the field edges for oviposition. In North Dakota and Montana, where *M. mexicanus* is usually the most important species, the numbers of live grasshoppers and egg pods found in the fields are of greater significance. This species is inclined to scatter its eggs throughout the stubble-fields. *C. pellucida* has the proclivity for seeking short sod for oviposition and does so in more or less well-defined egg beds. In rating an infestation of this species, the size of the egg beds should be considered as well as the numbers of grasshoppers and egg pods. The egg-laying habits of the most important species in the area being surveyed must be considered and all of the likely places for oviposition carefully examined.

As to the question of a combined rating for a mixed population such as a combination of eggs of *M. mexicanus* and *C. pellucida*, the first thing to do is to determine the kinds and numbers of pods per square foot in both places. The eggs of different species have to be learned in the field, and even then this can be done only in a general way. For example, eggs of *M. mexicanus* are cream colored and in more compact pods than those of *C. pellucida*, which are more tannish or light brown, and much closer to the soil surface. Eggs of *M. bivittatus* and *M. differentialis* are olive green with the latter color of a lighter shade, but there is a great variation in the eggs of both these species. If there is an abundance of both species, the rating should be increased, but not proportionately. It must be borne in mind that under these circumstances the same amount of ground will have to be covered to control the *M. mexicanus* found there regardless of whether *C. pellucida* is present or not. The presence of the latter, however, adds something to the quantity of material needed to effect complete control of both species; therefore the rating should be increased from a half point to a point, but not necessarily in proportion. Every field examined presents more or less of a individual problem, and the observer must use his best judgment in gauging infestations.

D. *Size of Egg Pods in Rating Infestations.*—Very little consideration has been given above to the size of the pods in evaluation of counts. When faced with some of the wide differences in size which occur between certain species, however, the observer can use a reduction factor on his total count in case of the small pods if he is consistently dealing with them. Whenever such a factor is used it should be noted. For example, in certain parts of the 1935 survey there were heavy infestations of *Ageneotettix deorum* and *Aulocara elliotti* where the numbers of pods ran as high as 50 to the square foot in bare spots in the fields. With both these species the pods contain only about six eggs each; therefore the average number of pods per square foot in this case should be reduced to about one-third. In such complex situations the judgment of the observer should again be exercised.

RELATIVE IMPORTANCE OF THE ADULT-GRASSHOPPER AND THE EGG SURVEYS.—The chief complaint against the utility of adult surveys has been that the grasshoppers move away from the places where they were located during the adult survey and are not where they were supposed to be when the egg survey is made. Shifts of this nature, of course, reduce the value of the adult survey and make it more difficult to arrive at a true infestation rating for a county. Even under such conditions, the adult survey still has some value, for it will indicate the counties where adults were most numerous and where eggs should be searched for most diligently even though they are not to be found in the same locations. The adult survey also shows the species to be dealt with in making the egg survey and the type of egg-laying areas to be inspected.

The adult survey has some distinct advantages over the egg survey. In the first place, live grasshoppers are easily located and the populations can be rapidly estimated. During an adult survey, some 20 to 30 stops a day can be made, and, in the usual short time allotted, a large territory can be completely and thoroughly surveyed as to the location and extent of infestation and the relative abundance of different species. From 10 to 15 minutes time is all that is necessary at any one place.

On the other hand, populations shift about considerably under hot-weather

conditions, and egg deposition may not occur in the exact spots where grasshoppers were recorded in the adult survey, although they can usually be located somewhere else in the vicinity. From the standpoint of prediction, a large number of adults in July does not necessarily mean that a proportionately large number of eggs will be deposited later on. Extreme heat and drought may destroy adult grasshoppers and delay oviposition so that few eggs are laid. Other factors such as fungous disease, parasites and a short season due to rains may reduce the amount of egg deposition. Accurate estimates of populations cannot be made of grasshoppers roosting in trees during extremely hot weather. These comprise some actual disadvantages of the adult survey.

The real index to the number of grasshoppers which might occur in any locality during any year is of course the number of egg pods deposited there the summer and fall before. Therefore it becomes necessary to follow an adult survey with a thorough egg survey if only to check on the extent that egg deposition has occurred. As a basis for prediction, the egg survey is more nearly accurate for any one field than for larger areas. The chief disadvantage of the egg survey, however, is the fact that egg pods are much more difficult to find than are live hoppers. Only certain types of places are selected for oviposition, and one must become familiar with all the variations that may occur within these types as well as with the different egg-laying habits of the different species. When a number of variations occur—as they often do—in one spot, a marked preference is shown by the grasshoppers for certain of these variations. All of these things must be known before one develops a good "nose" for eggs and can make a dependable egg survey.

Regarding the relative importance of the adult and egg surveys, the answer is that one supplements the other and each is valuable in its own way. A good general picture of conditions can be obtained by a thorough adult survey. The general areas of infestation can be located and the relative abundance of the different species determined. Then, if a certain proportion of the inspection stations or stops visited in the adult survey are again visited for eggs and careful examinations made of the extent of oviposition at each stop selected, the amount of egg deposition over the whole area can be more reliably determined. Suppose that in a county a proportion of one out of five stops in the adult survey were examined for eggs, taking into consideration local shifts, of course; then suppose the ratings obtained on the egg survey were less by one-half to 1 point than the ratings given by the adult survey; all of the ratings given that county in the adult survey can then be reduced by a half-point to 1 point. In this way a complete coverage of territory is obtained and a thorough study made of the real index for prediction and extent of oviposition.

METHOD FOR DETERMINING PERCENTAGE OF CROP ACREAGE INVOLVED OR BAIT ACRES IN EACH COUNTY.—The method used is to convert the ratings, at each stop in a county, into percentages of infestation (for the adult survey and the egg survey, respectively), using the conversion table set up in the original article (Shotwell 1935), which is based on the proportion of the grasshopper-susceptible crop acreages for the county. Then for the county the percentages of infestation for all the stops are averaged to obtain a single figure for the county for each survey. This method gives a different result from that obtained by averaging ratings and then converting.

The reason for this difference is that the scale of 0 to 100 per cent infestation is not equally divided for the five ratings. These ratings of 1 to 5 are convenient for scoring the results of a stop. When converted into percentages of infestation, however, each rating represents the degree of infestation of one portion of a certain number of equal portions of the county. For example, if 20 stops are made, each percentage is a measure of one-twentieth of the involved area, provided, of course, that the stops are well distributed.

After the average percentages are obtained for the adult and egg surveys, the final percentage of infestation for the county is determined by one of the three following methods which do not follow any hard-and-fast rule:

1. More importance is placed on the results of the egg survey in making estimates. In case this survey has been ade-

quate and the average percentage of infestation obtained is equal to or greater than that obtained from the adult survey, the figure obtained from the egg survey is used.

The number of eggs deposited is the true indication of what can happen the following year. In case a higher infestation is obtained in the egg survey than in the adult, this can well be attributed to migrations or to favorable weather conditions for egg deposition. The extent of oviposition depends largely upon the effect of weather conditions on the longevity and productivity of the grasshoppers.

2. In case the average percentage of infestation obtained from the egg survey is less than that obtained from the adult survey, the result of the egg survey is weighted by 2 and that of the adult by 1, and these are averaged for the final percentage of infestation in a county. For example, if the average for the egg survey is 17 per cent and for the adult survey 31 per cent, then $2 \times 17 = 34$, plus $31 = 65$ per cent; $65 \div 3 = 22$ per cent infestation for the county. Thus, twice as much importance is placed on the egg survey as on the adult survey.

In the egg survey there is the chance of missing egg beds or breeding spots (for want of better terms) when examinations are made at the various stops. If the average infestation indicated by the egg survey is less than in the adult survey, the former is raised as a safety measure, on the basis of the 2-to-1 rule of weighted importance. If it were not for this likelihood of overlooking the presence of eggs, a lower rating in the egg survey could be attributed entirely to reduced oviposition due to one cause or another. It is better, however, to be safe than to use actual figures in this case.

The adequacy of a survey in a county can be determined by a study of the survey data. Inadequate surveys are difficult to evaluate in any way. When both egg and adult surveys are believed inadequate it is best to balance the results of the two surveys by using the 2-to-1 rule. This is done regardless of whether the egg percentage is higher or lower than the adult. Where only a few stops have been made, one or two exceptional ratings sometimes occur which may raise the average out of proportion.

In all of this we are endeavoring to develop a logical procedure for obtaining a numerical estimate of the amount of control that will be necessary for infestations in a county. There is no attempt to set up hard-and-fast rules for predicting anything so variable as grasshopper infestations and their control.

ESTIMATING QUANTITIES AND COSTS OF NEEDED CONTROL MATERIAL.—After determining the average percentage of infestation, or, in other words, the percentage of crops infested, the method of estimating quantities of bait (dry) needed for control in each county has been as follows: The total crop acreage (grasshopper-susceptible crops in each county) $\times$ percentage of infestation (in decimal form) $\times 10$ pounds of bait (dry) per acre = pounds of bait needed. This amount reduced to tons $\times \$25$ per ton = cost of control.

The expression "total crop acreage" must be qualified to fit the character of infestations in certain crops. Whole acreages as recorded in crop statistics cannot be used, as the amounts of material thus obtained by the method just described would far exceed what would be actually needed. In many crops the infestations are restricted to field margins, and in this case the quantities of bait necessary to poison one-half or one-fourth of the whole area of the field are usually sufficient to go around the edges about three times, depending on the type of field. A figure equal to one-half the acreage is used in the case of small crop fields which have a greater proportion of field margin and a one-fourth acreage is used for larger fields, such as corn and winter wheat, where in proportion there is less headland. In these fields the ground is usually intensively cultivated with little chance for egg deposition or hatching except along their uncultivated edges. Experience has taught that good control can be obtained by early concerted action along these margins, and that it is not often necessary to poison entire fields.

In the hard-spring-wheat areas where the dominant grasshopper, *Melanoplus mexicanus*, scatters its pods throughout the stubblefields, whole wheat acreages have to be included. Even then, in the worst outbreaks, not all of the fields are involved at first, but complete destruction comes from grasshoppers moving from field to field. Therefore, in figuring

quantities of bait needed, the limits of infestations must be considered. Prolonged periods of hatching increase the number of baitings and complicate the matter of making estimates.

Total acreages are used for spring wheat, oats, rye, barley, millet, flax and sometimes alfalfa; one-half acreages for sugar beets and truck crops; one-fourth acreages for winter wheat, corn, pasture (both woodland and plowable) and cotton.

Neither wild nor cultivated hay other than the legumes and millet has been considered because in the past very little control has been needed in such fields. The other crop acreages should take care of the control needed for invasions from this source. The exclusion of this type of hay crop is, of course, a debatable question.

SUMMARY.—In the general plan three major kinds of survey are required, *viz.*, nymphal, adult and egg. In the spring there is a limited egg-survival survey previous to and as a part of the nymphal survey to determine the effect of drought, parasites, and predators on the numbers of eggs. The nymphal survey is used as a check on the previous fall survey to improve the accuracy of predictions. The adult and egg surveys are used for qualitative and quantitative studies of grasshopper populations from year to year and to locate and determine for the following year the extent of infestations and the quantities of material needed for control. For this purpose a larger area can be covered in a shorter time by the adult survey than by the egg survey, but the results are less dependable. It is harder to locate egg pods than live grasshoppers; therefore the egg survey is slower, but the number of eggs is the real index of what is to be expected the next year. The adult survey and the egg survey each has its advantages and disadvantages and must be adapted to varying conditions in different localities.

Populations in the nymphal and adult surveys are estimated in numbers per square yard, by direct observation. In the egg survey the numbers of egg pods are estimated in numbers per square foot by counts made in favorable egg-laying places. There are four methods of sampling for egg pods, each applicable to a particular condition. These are (1) sifting unit quantities of soil taken to a depth of three inches; (2) shaving the surface of bare soil or sod, exposing the tops of the egg pods for counting; (3) cutting out small unit areas of sod; and (4) digging or pulling single plants or clumps of grass for counts of pods, per plant or clump, around or among their roots. The method used is based on the egg-laying habits of the species present and the conditions imposed by the particular environment.

The results of the adult and egg surveys are combined to determine the average percentage of infestation for each county. This percentage is then applied to the total grasshopper-susceptible crop acreage for each county to determine the actual bait acreage. The bait acreage multiplied by 10 pounds per acre gives the quantity of material needed for control. Only certain proportions of some crop acreages are included because of the character of the infestations in these crops, due to cultural conditions and to the selective egg-laying habits of the species involved.—3-23-38.

LITERATURE CITED

Shotwell, R. L. 1935. Methods for making a grasshopper survey. JOUR. ECON. ENT. **28**(2):486–91. April.

IMPORTANT changes were made in the revision of Federal quarantine regulations relating to white-pine blister rust, which became effective on July 1. The present requirements, according to the Bureau of Entomology and Plant Quarantine, are designed to protect two pine-growing regions in which the blister rust has not been found, one comprising the southeastern states of Georgia, Kentucky, North Carolina, South Carolina and Tennessee, and the other the western States of Arizona, Colorado, Nevada, New Mexico, Utah, Wyoming and part of California. Five-leaved pines are prohibited movement into these states (excepted between and among them) and Ribes shipments thereto are required to be dipped or dormant and defoliated. To protect the control work which has been and is being carried on in various pine-growing regions throughout the country, the control-area permit requirement in consigning currant and gooseberry plants to such regions is continued and extended to 23 states.

The Host Plants and Parasites of the Cowpea Curculio and Other Legume Infesting Weevils*

THEODORE L. BISSELL, *Georgia Experiment Station, Experiment*

In a search for host plants of the cowpea curculio, *Chalcodermus aeneus* Boh., in central Georgia, collections of more than 20 species of wild and cultivated legumes were made during the summer and fall months of 1936 and 1937. Besides the cowpea curculio, numerous other weevils and parasites were procured from the seeds and are here reported.†

Unless otherwise stated, the collections were made in Spalding County, Ga. The seed pods were placed either in glass jars or in lantern globes with cloth tops and screen bottoms set on jars to catch emerging grubs and adults. Water was supplied directly to the seeds at irregular intervals. The weevil grubs were put on soil so that they might burrow and complete their development. In a few collections seed was caged individually to get more definite information on parasites.

The insects listed were determined by specialists of the taxonomic division of the Bureau of Entomology and Plant Quarantine, Washington, D. C. The plants were identified by Dr. W. A. Jenkins, Georgia Experiment Station, and verified by Dr. S. F. Blake of the Bureau of Plant Industry, Washington. The plant names are those used in Small's *Manual of Southeastern Flora* (1933).

Table 1.—Percentage of cowpeas infested by curculio in variety plots at Experiment, Ga.

VARIETY	1936	1937
Early Ramshorn Blackeye	38.20	Not planted
Extra Early Ramshorn Blackeye	23.46	64.05
Large White Blackeye	23.03	65.02
California Blackeye	22.38	61.84
White Mush	22.70	65.65
Red-Spotted Crowder	19.15	59.81
Jumbo Blackeye	12.16	49.70
Virginia Blackeye	9.03	49.23
Conch	6.18	39.49
New Era	Not planted	27.61
Victor	Not planted	26.43
Brabham	3.33	26.29
Whippoorwill	3.22	43.88
Groit	2.02	33.23
Average of all varieties	*15.36*	*46.03*

* Paper No. 53, Journal Series, Georgia Experiment Station.

† Since this paper was written, the cowpea curculio has been found infesting pods of catjang and asparagus bean planted among cowpeas. These are designated as botanical varieties of *Vigna sinensis: V. s. cylindrica* and *V. s. sequipedalis*, respectively, by Morse in U.S.D.A. Farmer's Bulletin 1148, 1920.

CHALCODERMUS AENEUS BOH.—As far as observations go, the cowpea is the favorite host of this weevil. About 35 varieties were grown at Experiment, Ga., during the two years and all were infested, to varying degrees. These included blackeyes, whites, crowders of various colors and field peas, or those grown for stock feed and soil improvement. Table 1 gives the percentage of infestation (including all peas injured by adults and larvae) of varieties that were outstanding both years either for high or for low infestation.

The four varieties of blackeyes at the top of table 1 were indistinguishable in seed characters and were similar in earliness. It will be noted that Jumbo and Virginia Blackeye were consistently less highly infested. Whippoorwill and Conch were among the least infested in 1936, but not in 1937. About three times as much damage was done to the cowpeas in the variety plots in 1937 as in the first year.

String beans have been found infested with larvae of *C. aeneus* in Pike and Tift counties, in central and southern Georgia, respectively. In southern Georgia the insect has done severe damage to beans maturing for seed, but the infestation of beans in the snap stage has not been appreciable.

One wild host of the cowpea curculio has been found, namely, *Strophostyles umbellata* (Muhl.) Britton, called "wild bean." It is a perennial plant with trailing stems and pods borne on upright peduncles somewhat after the manner of the cowpea, but the pods are much smaller (figs. 1 and 2). It has been found in poor soil along railroad tracks and washes. In 1937, pods were first observed August 20, but they did not become abundant until the middle of September. Adult curculios were found on the plants in the field during September. Grub issued from picked pods between September 13 and October 25, from which 37 adults matured. The average weight of 16 live

adults was 11.4 per cent less than that of curculios bred from cowpeas. This wild bean does not appear very important from the standpoint of cowpea infestation because of the comparative scarcity of the plant and because of its late maturity. However, cowpeas might readily become infested from stands of *Strophostyles* of the previous year.

CHALCODERMUS COLLARIS HORN.—This species was bred profusely from the partridge peas *Chamaecrista robusta* Pollard and from *C. procumbens* (L.) Greene (*C. nictitans* L.), the former collected in Spalding County and the latter in Pike and Clarke counties. One specimen of *C. collaris* was collected on cowpeas in July, 1936, but this species was not found infesting cowpea pods.

In a recent paper Alsterlund (1937) gives *Cassia chamaecrista* as a host of *Chalcodermus collaris* in Illinois. Small (1933) lists this name as a synonym of *Chamaecrista fasciculata* (Michx.) Greene; therefore, the weevil is known to infest three species of this plant genus.

CHALCODERMUS INAEQUICOLLIS HORN.—This weevil has been bred from pods of two small vines, *Galactia volubilis* (L.) Britton and *Bradburya virginiana* (L.) Kuntz, the former collected in Lamar County and the latter in Spalding and Mitchell counties. In this species there was higher mortality of grubs in the soil cages than in the cages of *C. aeneus and C. collaris*, and only four individuals have been carried to maturity in the two years.

PARASITES OF *CHALCODERMUS*.—The tachinid fly *Myiophasia globosa* Tns. was bred in large numbers from *Chalcodermus aeneus* in cowpeas and once from string beans. One specimen also emerged from a larva of *Chalcodermus collaris*. This fly is known to breed in the plum curculio and several other species of *Conotrachelus* and is also a fairly common parasite of the boll weevil. *Microbracon mellitor* (Say) was found in cowpeas infested with curculio. Three species of Hymenoptera emerged from the pods of *Galactia* in 1937, presumably parasitizing *Chalcodermus inaequicollis*. These were *Callimome anthomyiae* (Ashm.), *Galeopsomyia* sp. and *Zatropis coeliodis* (Ashm.)

FIG. 1.—*Strophostyles umbellata* (Muhl.) Britton, a wild bean; showing habit of growth and size of pods as compared with cowpeas.

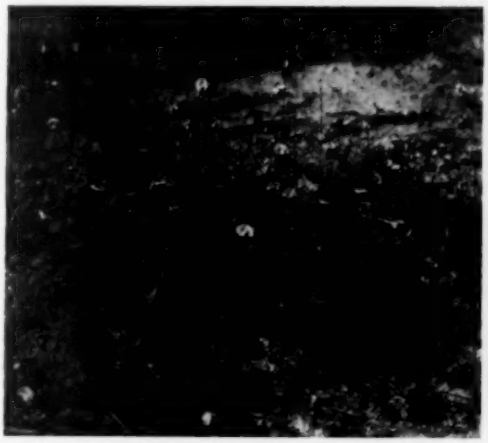

FIG. 2.—*Strophostyles umbellata* with flowers and pods, a wild host plant of the cowpea curculio.

APION CRASSUM FALL.—This species was bred freely from pods of *Martiusia* (*Clitoria*) *mariana* (L.) Small, a butterfly pea. About five adults were found in a pod. It appears they do not make exit holes but wait for the pods to open. In 1937 very little seed was made in Spalding County due to weevil infestation of the young pods. Two specimens of *Zatropis incertus* (Ashm.) and one of *Acolus* sp. emerged from one lot of pods, in company with the weevil, but C. F. W. Muesebeck writes that the latter is "almost certainly a parasite of spider eggs."

APION DECOLORATUM SMITH.—This species was bred from the seed of two species of beggarweed: *Meibomia marylandica* (L.) Kuntze and *M. canescens* (L.)

Kuntze; from three species of *Lespedeza: L. procumbens*, Michx., *L. frutescens* (L.) Britton and *L. virginica* (L.) Britton; one specimen from *Galactia volubilis*. Infested seed of all species was collected in Spalding County and in addition infested *L. frutescens* and *L. virginica* were collected in Mitchell County and *L. procumbens* in Clarke County.

Four species of hymenopterous parasites also emerged from these seed, as follows: *Zatropis incertus* (Ashm.), *Catolaccus fragariae* Roh., *Catolaccus* n. sp. and *Horismenus microgaster* (Ashm.). The first two were found to be primary parasites of *Apion decoloratum* by rearing from individual seed of *Lespedeza procumbens*. One pod, which contained one seed, supported one weevil grub, and in turn one parasite came from one grub. The other Hymenoptera may have been weevil parasites or secondaries. *Zatropis incertus* was the most numerous. From ten lots of *Meibomia* and *Lespedeza* seed caged in 1936 there emerged 82 weevils, 234 *Zatropis* and 22 other parasites. The indicated parasitism of 74 per cent is only approximate as there had been emergence of weevils and parasites before collection. *Zatropis incertus* is known as a minor parasite of the boll weevil and is recorded from numerous other species of weevils. *Catolaccus fragariae* was described by Rohwer (1934) as a parasite of the strawberry weevil.

APION GRISEUM SMITH.—This weevil was bred from two wild beans. The first *Phaseolus polystachus* (L.) B. S. P., was heavily infested. From about two quarts of pods collected November 10, 1936, there emerged 569 weevils, without any parasites. In 1937 only seven pods were collected. Of these, six were infested by *A. griseum*, averaging 11.2 weevils to the pod. In two of the pods there were 11 *Zatropis incertus* parasitizing *griseum*.

In 1937 several specimens of *A. griseum* were bred from one lot of pods of *Strophostyles umbellata*.

APION SEGNIPES SAY.—This species emerged from pods of *Cracca virginiana* L. collected in Mitchell County. It was not bred from *Cracca spicata* (Walt.) Kuntze collected both seasons in Spalding County.

AMBLYCERUS ROBINIAE (FAB.).—This common bruchid was bred from pods of *Gleditsia triacanthos* L., honey locust, collected in 1936, and a green hymenopterous parasite, *Horismenus missouriensis* (Ashm.), was reared from individual larvae of the weevil. From 18 to 30 parasites, 63 per cent of which were males, came from each bruchid larva. Two specimens of *Heterospilus bruchi* Vier. emerged from the same pods, but the host of this parasite was not determined.

BRUCHUS PISORUM (L.).—This weevil was found infesting seed of the Austrian winter pea grown in Spalding County. The weevil was parasitized by *Eupelmus cyaniceps* var. *amicus* Gir. emerging late in June, 1937.

The pods of two coffee weeds, *Emelista* (*Cassia*) *Tora* (L.) B & R. and *Ditremexa occidentalis* (L.) B. & R., were collected in quantity but produced no insects.—2-11-38.

LITERATURE CITED

Alsterlund, John. 1937. Notes on the biology of the partridge-pea weevil, *Chalcodermus collaris* Horn. (Coleop., Curculionidae.) Ent. News, **48**(2):31–35.

Rohwer, S. A. 1934. Descriptions of five parasitic Hymenoptera. Proc. Ent. Soc. Wash. **36**(2):43–48.

Small, John Kunkel. 1933. Manual of the southeastern flora. 1554+xxii pp. New York.

HAWAIIAN rule 32, issued September 23, 1937, requires fumigation for the cabbage maggot of horseradishes, radishes, rutabagas and turnips brought commercially from the continental United States.

BASED upon negative results of intensive Federal surveys for the alfalfa weevil in Clark County, Nev., during the past two years, the state of California removed the county from quarantine under an amendment, effective May 11, to quarantine proclamation 7. Lander County, Nev., and Custer County, S. D., were added to the area in this amendment.

THE ORIENTAL fruit moth quarantine proclamation of California was revised, effective April 22. This revision adds New Hampshire to the area under quarantine, extends the period during which budwood of host trees is admissible under permit from the quarantine area to April 1, instead of March 1, and adds haw or hawthorn to the host list.

MODOC COUNTY, Calif., Custer County, S. D., and four additional counties in Wyoming were brought within the area designated as infested with alfalfa weevil under a revision of the Illinois quarantine dated March 28.

A Preliminary Study of the Biology of *Scolytus sulcatus* LeC.*

L. L. Pechuman, *Cornell University, Ithaca, New York*

Foreword

In 1935 a single specimen of Scolytus sulcatus *LeC. was found feeding in a twig crotch of an American elm in Westchester County, New York, by Dr. P. A. Readio. Since that time* S. sulcatus *has been found to be abundant in certain areas within the so-called Dutch elm disease zone, breeding in both apple and elm, and during the summer of 1937 it was observed in several locations in Westchester County under circumstances such as to arouse suspicion that, in specific instances, it may have been the agent of transmission of the Dutch elm disease fungus. In the literature there is a conspicuous lack of information relative to this beetle. In view of these facts a study of* S. sulcatus *with particular reference to its potentialities as a vector of the Dutch elm disease organism has been undertaken by the Dutch elm disease laboratory of the New York State College of Agriculture. The present paper is a summary of our knowledge to date relative to the biology, habits and distribution of the species.*

Donald L. Collins

Scolytus sulcatus was described by LeConte in 1868 from a single specimen from "New York." In 1876 LeConte republished the description and included the species in a key. Subsequent writers, Blatchley & Leng (1916), Swaine (1918) and others have placed *S. sulcatus* in keys using LeConte's description as a basis. In "A List of the Insects of New York" (Leonard 1928), *S. sulcatus* is reported from Rochester, N. Y., by George Moore and R. N. Wendt. The present location of the specimen or specimens on which this record is based is unknown, and it has been impossible to have it verified. However, except for this rather doubtful record, no specimen of *S. sulcatus* except the unique type was known for 65 years.

Blackman (1934) reported *S. sulcatus* collected from elm in 1933 at Chatham, N. J., by W. D. Buchanan. At the same time Blackman lists the species from several localities in southeastern New York, northern New Jersey and western Connecticut, these records based on specimens collected in 1934.

In 1936 Dietrich (1936 a & b) reported it from the lower Hudson Valley north to Albany and west to Cicero and Pulaski. In 1937 he found it near Tully and Oswego, and the writer found it at Ithaca. The northernmost record is Willsboro in Essex County. It has been found in several localities along the Mohawk Valley and up the Delaware as far as Port Jervis. It appears to be especially common in southeastern New York in the counties of Westchester, Putnam, Rockland and Orange. It has also been noted in the Bronx and on Long Island in the vicinity of Babylon. Taking into consideration all the available records, *S. sulcatus* has been found in 17 counties in New York state.

The reason for the sudden "reappearance" of *S. sulcatus* is open to conjecture. It has been suggested that it has been present in comparative abundance all the time, but has been overlooked because of its small economic importance. The special attention given to the study of elm insects since the initiation of work on the Dutch elm disease problem has been responsible for most of the new records of the species. It is probable that the severe winter of 1933–34, which killed or injured many apple trees in the Hudson Valley, provided an abundance of breeding material for *S. sulcatus*, resulting in a great increase in a previously small population. The concentration of *S. sulcatus* in southeastern New York suggests the possibility that the species is not native, but has been introduced in the vicinity of New York City and is slowly spreading north and

* The suggestions and assistance of Prof. P. A. Readio and Dr. D. L. Collins, who are in charge of the entomological activities of the joint Dutch elm disease investigation project conducted by the Departments of Entomology and Plant Pathology at Cornell University, are greatly appreciated. Information from Dr. M. W. Blackman and Dr. K. G. Blair regarding the taxonomic status of *Scolytus sulcatus* LeC. is also appreciated. Special acknowledgment is due Dr. Henry Dietrich who not only made many valuable suggestions but who also turned over to the writer a list of localities where he had collected *S. sulcatus* in New York state. Most of the work involved in this study was done at the Boyce Thompson Institute for Plant Research at Yonkers, New York. Most of the photographs were taken by L. P. Flory and other members of the illustrating division of the Institute; those of the adults were taken by W. G. Bodenstein.

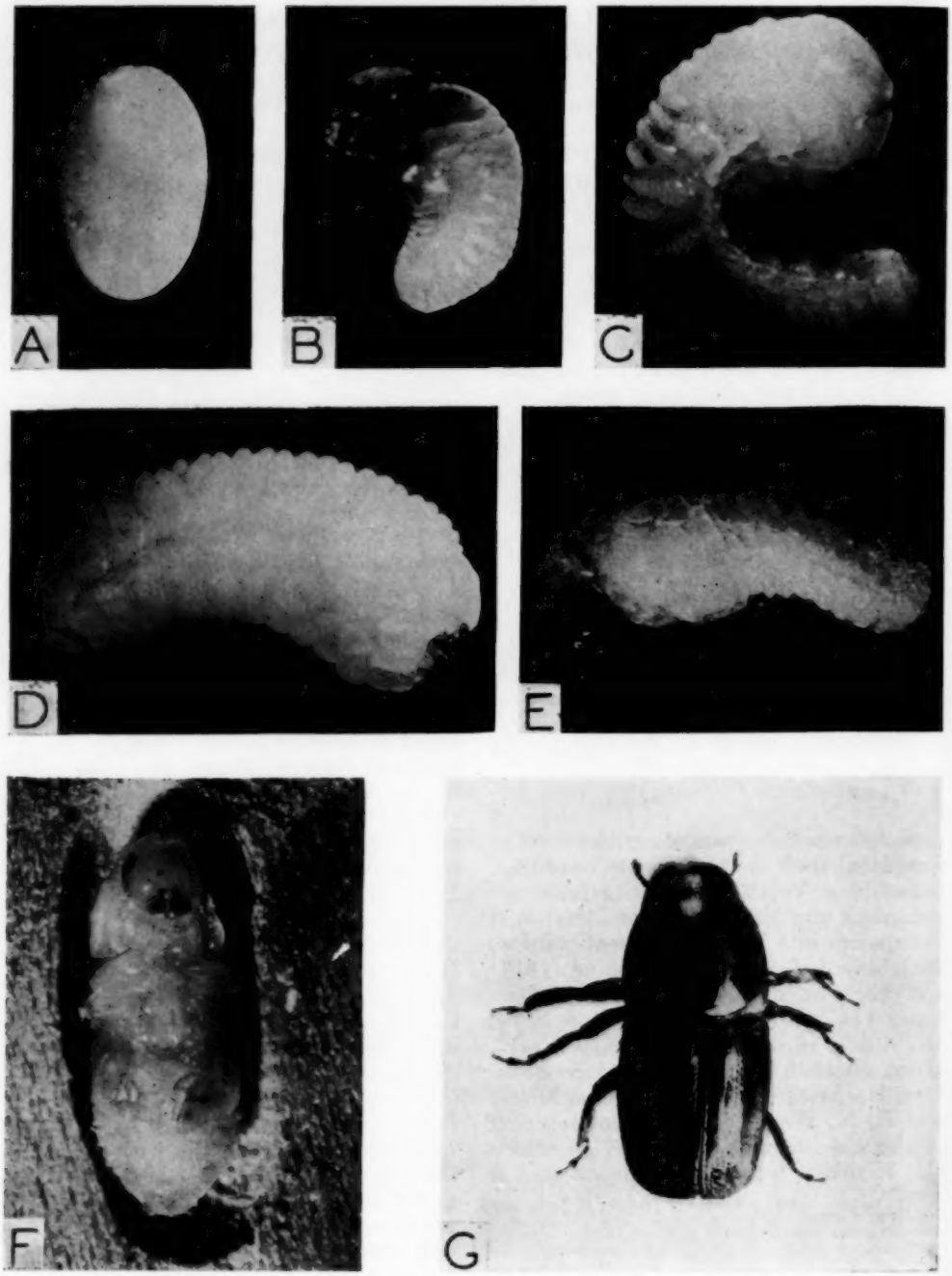

FIG. 1.—A. Egg of *Scolytus sulcatus* (×40). B. First instar larva of *S. sulcatus* (×40). C. Mature larva of *S. sulcatus* (×12). D. Mature larva of *S. sulcatus* in form in which it overwinters in cell (×12). E. Prepupa of *S. sulcatus* (×12). F. Pupa of *S. sulcatus*, ventral aspect, in pupal cell (×12). G. Adult male of *S. sulcatus*, dorsal aspect (×12).

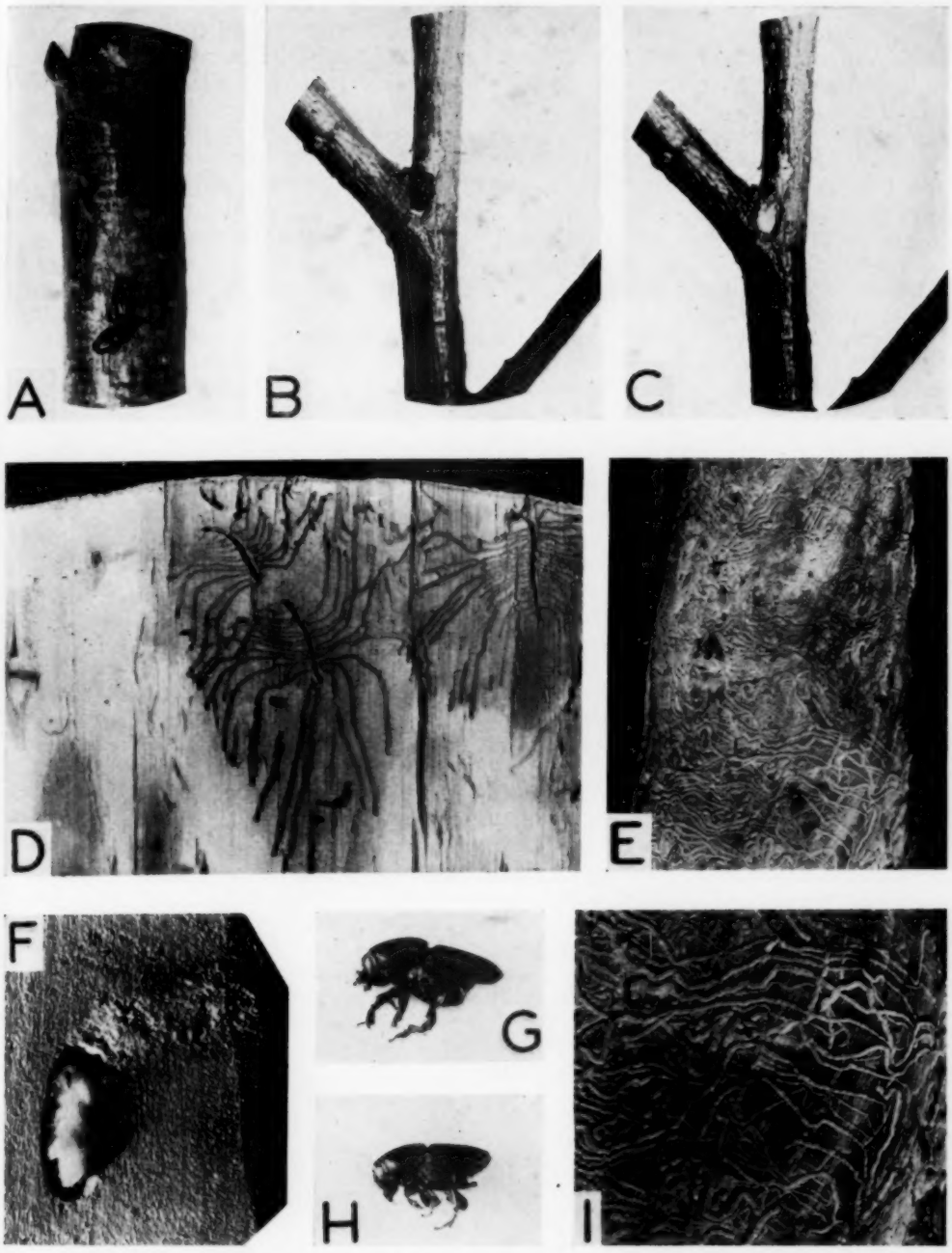

FIG. 2.—A. Two adults of *Scolytus sulcatus* feeding on side of elm twig (×1.6). B. Adult *S. sulcatus* feeding in crotch of elm twig (×1.6). C. Wound in crotch of elm twig made by specimen in B (×1.6). D. Tunnels of *S. sulcatus* in elm bark (×0.5). E. Advanced tunnels of *S. sulcatus* in apple wood (×0.25). F. Pupa of *S. sulcatus*, lateral aspect, in cell; note frass filled tunnel leading to surface (×3.7). G. Adult male of *S. sulcatus*, lateral aspect (×5). H. Adult male of *S. multistriatus*, lateral aspect; note ventral spine (×5). I. Tunnels of *S. sulcatus* in apple; enlarged portion of E (×0.5).

west. Dr. Blackman has made a rather thorough study of the Palearctic species of *Scolytus* and has informed the writer in correspondence that he believes *S. sulcatus* to be distinct from any known species of *Scolytus*. *S. sulcatus* does, however, bear a decided resemblance to the European *S. mali* Bechst., both in structure and habits, and Dr. K. G. Blair of the British Museum (Natural History) states in correspondence that he thinks they are the same species. For the purposes of this paper *S. sulcatus* will be regarded as a distinct species.

HOSTS.—LeConte did not give the host of *S. sulcatus* when he described the species, and subsequent workers had no further information. Most of Blackman's specimens came from elm but he also had specimens from apple and plum. Dietrich gives both elm and apple.

The writer has frequently found *S. sulcatus* running about on the surface of felled elms and has on several occasions found the species breeding in the weakened portions of living elms, *Ulmus americana*. Cut elm logs used as traps for *S. multistriatus* have also been found to furnish breeding places for *S. sulcatus*. The writer has also successfully reared *S. sulcatus* under experimental conditions on freshly cut elm logs.

Apple is a favorite host of *S. sulcatus* and in the field is more frequently found to be attacked than is elm. Under experimental conditions, however, little choice seems to be exercised, and elm is attacked as readily as apple. Apple is probably the usual host, but the life cycle of the insect proceeds normally in elm as well. Slippery elm, *Ulmus fulva*, is also subject to attack in the field.†

DESCRIPTION.—The adult beetle has a shining black pronotum and dark reddish brown elytra; in some specimens the elytra are nearly black and in immature individuals they tend to be pale yellowish brown, figs. 1 and 2. *S. sulcatus* may be separated from all Nearctic species of *Scolytus* by the following combination of characters: abdominal sternites unarmed in both sexes, elytra glabrous, fifth sternite without an elevated posterior margin in the male, elytra with striae weakly impressed and with the punctures little coarser than on the interspaces. In the field, *S. sulcatus* may easily be separated from other species of *Scolytus* found in the same host; from *S. rugulosus* in apple by the glabrous elytra and much larger size; from *S. multistriatus* in elm by the absence of the long spine on the second sternite. *S. sulcatus* is also somewhat larger than *S. multistriatus;* measurements of 20 males and 20 females of each species taken at random gave the following results: *S. sulcatus* males, 3.21 to 4.8 millimeters, average, 3.94 millimeters; females, 3.92 to 4.8 millimeters, average 4.36 millimeters; *S. multistriatus* males, 2.49 to 3.57 millimeters, average, 3.19 millimeters; females, 2.85 to 3.92 millimeters, average, 3.37 millimeters. The sexes of *S. sulcatus* may be distinguished by the somewhat longer fifth abdominal sternite of the female, which has a raised arcuate posterior margin.

LIFE HISTORY AND HABITS.—Emergence of the adults begins in late May in southeastern New York. In 1937 emergence from both apple and elm began on May 27 and adults were observed running about on the bark of freshly cut elm logs on May 29. The peak of emergence in 1937 was during the first week in June although emergence continued in the caged experimental material until the third week in August.

Several European workers have reported a decided preponderance of males over females in *S. scolytus* and other species. To ascertain if this were true for *S. sulcatus*, a record of the sex of specimens emerging each day was kept for several lots of material. The results indicated that the total emergence of each sex from a given lot of material is about equal. For example two representative lots produced 77 males and 76 females and 112 males and 103 females, respectively. In all cases, however, the males emerged first; sometimes the emergence would be 100 per cent males for several days before a female appeared. The daily emergence of the females soon equaled that of the males and then surpassed it. The few specimens which appeared after the main emergence was over were in almost all cases females.

Adults of *S. sulcatus* were still found in the field on September 14, but this does not necessarily mean that emergence was taking place at this time, as the adults

† Since this paper was written Dr. Dietrich has found *Scolytus sulcatus* breeding in mountain ash, *Sorbus americana*, and the writer has found it in peach.

are able to live for a considerable period. Specimens kept at a constant temperature of 20 degrees C. and provided with fresh elm twigs every 3 days lived a maximum of 40 days, and specimens similarly kept at 10 degrees C. lived a maximum of 78 days. There was no apparent difference in the length of life of males and females. During this period feeding on elm twigs was continuous and abundant. The potential importance of *S. sulcatus* as a vector of *Graphium ulmi* is emphasized when it is realized that considerable feeding on elm twigs may take place before egg laying. The length of the feeding period between emergence and re-entry has not as yet been determined under field conditions.

Feeding of some sort by the adult appears to be necessary before the eggs are laid. This may be in the form of twig feeding on apple or elm or as so-called "trial" tunnels in the host tree. Twig feeding is of primary importance, as the wound so caused becomes the infection court for the spores of *G. ulmi* which may be deposited there by the beetles. Feeding on elm twigs in the field was first found by Dr. P. A. Readio on June 29, 1935 in Westchester County. Under experimental conditions, feeding on elm twigs is very abundant, the feeding wound resembling that of the European *S. scolytus* more than that made by *S. multistriatus*. With *S. multistriatus* the wound is nearly always in a twig crotch or at the base of a leaf petiole and is usually quite deep. Wounds made by *S. sulcatus* are on the sides of the twig as often as in a crotch and are usually broad and shallow. Frequently several beetles will gather at one spot and make a broad "patchlike" wound. Wounds made by males and females are about equally extensive. Under experimental conditions the beetles showed a slight preference for apple twigs, but this may have been due to their more succulent condition.

The term "trial" tunnels, which has been used to indicate certain activities of other species of bark beetles, is not correctly applied to all similar activities of *S. sulcatus*. Some tunnels of this species are short and largely in the bark, although they may reach the cambium; they are usually found in branches in which *S. sulcatus* is ovipositing. They may be made either by males or females and in the writer's opinion are used solely for feeding purposes. Dozens of these "feeding tunnels" may be found on a single branch, which may also contain tunnels with eggs or larvae. What might be termed true trial tunnels are also found; these consist of short maternal tunnels in which a few eggs are laid, after which the tunnel is deserted. In the laboratory it has been found that a single female may construct four or five such tunnels. *S. multistriatus* may also make feeding tunnels or construct several maternal tunnels, but this practice is not so usual as in *S. sulcatus*.

The dying or weakened branches of apple and elm are usually selected for breeding purposes, although freshly cut wood is also attacked. Fairly large branches seem to be preferred, 6 to 15 inches in diameter being the usual size; branches as small as 3 inches are sometimes attacked, and it is not unusual to find *S. sulcatus* breeding in the trunk of a dying apple tree.

The male apparently does not assist in the construction of the maternal tunnel. Only rarely is a male found in a tunnel with a female, as is usual with *S. multistriatus*. Mating was not observed but it probably takes place at the mouth of the tunnel. The entrance hole runs at a slight upward angle through the bark until it reaches the cambium; from this point the maternal tunnel proceeds upward between the bark and the wood. Its course is frequently sinuous but in general it follows the grain of the wood. The tunnel is typically of the simple unbranched type, but on one occasion a single tunnel with two arms was found; sometimes the tunnel tends to assume a horseshoe shape. The maternal tunnel is extremely variable in length, but it is generally longer and wider than that of *S. multistriatus*. The usual dimensions are 35 to 60 millimeters long and 3 millimeters wide. It varies, however, from 5 to 100 millimeters in length and 2 to 4 millimeters in width.

The eggs are laid in the usual fashion in niches along the walls of the maternal tunnel. They are adhesive and are packed in place by a sticky frass. Creamy white in color, they average about 0.81 by 0.504 millimeters. The total number of eggs laid in one maternal tunnel varies from 6 to 100, but the usual number is from 40 to sixty.

Under field conditions the eggs hatch in from 5 to 10 days depending on the

temperature, and the larvae begin to tunnel between the bark and wood against the grain and at right angles to the maternal tunnel. The first instar larva measures about 0.93 to 1 millimeter in length. As the larvae grow, the larval galleries tend to meander about considerably both with the grain and against it, frequently crossing each other. The larval galleries toward each end of the maternal tunnel usually turn and follow the grain and are more or less straight. A completed larval gallery may measure from 150 to 170 millimeters in length, but the average is shorter.

From the end of July until the middle of September the full grown larva, which may measure from 5 to 8 millimeters in length, constructs a cell 10 to 20 millimeters deep in the wood at the end of the gallery. In elms and in thick barked branches of apple trees, the cell may be more shallow or even between the bark and wood or in the bark itself, as in *S. multistriatus*. The entrance to the cell descends at an angle and may or may not turn and run with the grain of the wood. When the cell is completed the larva reverses itself and remains with its anterior end toward the surface. The exit to the surface is tightly packed with frass, which shows as a small white or yellowish circular area in surface view. By the time the cell is completed the larva has lost much of the typical scolytid curve of body and has decreased in size, rarely measuring over five millimeters in length.

The majority of the larvae of a given brood pass the winter in their cells. However, as is common with many wood boring insects, a few individuals of most scolytid colonies do not follow the typical life history. They do not form cells in the wood but remain in their tunnels under the bark. In the following spring or summer they may construct a cell, pupate and emerge the same season, or they may overwinter as larvae in cells and emerge as adults a year later than the other members of their colony. Also, larvae hatching from eggs laid late in the season remain under the bark and complete their development the following season.

In the first part of May the larvae which have passed the winter in cells in the wood begin to form prepupae and then pupae. Definite records on the length of the prepupal and pupal periods under field conditions are not available, but observations indicate that the prepupal period lasts from 5 to 8 days and pupal period from 10 to twenty days at the usual temperatures prevailing during May. In the laboratory it was found that at a temperature of about 25 degrees C. the prepupal period was two to three days and the pupal period seven days. The prepupa measures from four to five millimeters in length and the pupa about the same.

After transforming, the adult beetle remains in the pupal cell for several days until most of the normal coloration is attained. It then gnaws its way to the surface, sometimes by way of the frass filled tunnel constructed by the larva, but more usually by a separate opening through the solid wood. The exit holes in the bark average two millimeters in diameter.

Although adults of *S. sulcatus* are found throughout the season there is no evidence to indicate that there is more than one generation a year in New York although more than one would seem to be possible under unusually favorable conditions. An elm log in which *S. sulcatus* oviposited in May, 1937, was kept out of doors until September when it was placed at a more or less constant temperature approximating 20 degrees C. Although this log was at no time exposed to low temperatures, adult beetles emerged in December. This would indicate that a period of cold weather is not necessary before pupation. As mentioned previously some individuals require two years to complete their life cycle.

NATURAL ENEMIES.—Woodpeckers are probably the most important natural enemies of *S. sulcatus*. The writer has frequently found branches of apple trees in which every overwintering larva had been destroyed by these birds.

Competition with other insects probably exercises a greater controlling influence in elm than in apple. The larvae of *Saperda tridentata, Neoclytus acuminatus, Xylotrechus colonus* and other Cerambycidae are usually abundant in elm branches along with *Scolytus sulcatus* and probably the construction of their extensive galleries destroys many *S. sulcatus* larvae as well as reduces the food supply. The curculionids *Magdalis armicollis* and *M. barbita* and the scolytids *Hylurgopinus rufipes* and *Scolytus multistriatus* also are

competitors for food. *S. multistriatus* because of its shorter life cycle probably suffers less from the competition of other insects than does *S. sulcatus*. In apple only the buprestid *Chrysobothris femorata* and *Scolytus rugulosus* seem to be common competitors and they are not especially important.

There has been little opportunity to make observations on the predators and parasites attacking *S. sulcatus*. The larvae of Cleridae are often found in the larval galleries but never appear to be very abundant. Several braconid parasites have been reared in association with *S. sulcatus*, but their relations with their host have not as yet been determined. Large numbers of the flies *Lonchaea polita* (Lonchaeidae) and *Medeterus* sp. (probably *ciliata*—Dolichopodidae) have been reared from wood containing *S. sulcatus*. Other species of *Lonchaea* and *Medeterus* have been considered to be important controlling agents for other species of bark beetles and these may exert a similar influence on *S. sulcatus*.

SUMMARY.—*Scolytus sulcatus* LeC., after being "lost" for 65 years, has been found to be widespread in central and eastern New York, western Connecticut and northern New Jersey.

Apparently its favorite host is apple, but it frequently breeds in elm and it has been recorded from plum.

It is probably a distinct species, and the adult is not easily confused with any species of *Scolytus* likely to be associated with it.

Emergence in southeastern New York is from May until September with the peak in early June.

The adults are long lived, some living more than two months under experimental conditions.

The males emerge first in the spring, but the total emergence of each sex is about the same.

Feeding by the adults is probably necessary before eggs are laid; feeding may take place on twigs of elm or apple or in the bark of the host tree. Twig feeding on elm is of primary importance from the standpoint of the possibility of transmission of the Dutch elm disease organism.

Weakened or dying branches of elm or apple are usually selected for oviposition. The female probably does all the work in connection with the construction of the maternal tunnel, which is of a simple longitudinal type. The usual number of eggs is 40 to 60.

The larvae tunnel across the grain of the wood but as they mature they make tunnels which meander in all directions.

In late summer or fall the larva constructs a cell, in the wood or occasionally beneath the bark, in which the winter is passed. A few larvae overwinter beneath the bark and continue their development the following season.

A prepupa and pupa are formed in May. The adult does not emerge from the pupal cell for several days after transforming.

There is one generation a year in New York, but some individuals require two years to complete their development.

Woodpeckers are probably the most important of the natural enemies. Competition offered by other insects may also be important in elm. The value of the role played by insect predators and parasites is unknown.—2-26-38.

LITERATURE CITED

In the following references the complete pagination of the article is not given; only the page on which there is a reference to Scolytus sulcatus *LeC. is indicated.*

Blackman, M. W. 1934. A revisional study of the genus *Scolytus* Geoffroy (*Eccoptogaster* Herbst.) in North America. U. S. Dept. Ag. Tech. Bul. **431**: 5, 7, 12.

Blatchley, W. S., and C. W. Leng. 1916. Rhyncophora or weevils of north eastern America, pp. 588, 590.

Dietrich, Henry. 1936a. Elm bark beetles in New York state. JOUR. ECON. ENT. **29**: 217.

Dietrich, Henry. 1936b. *Scolytus sulcatus* LeC. on apple in New York state. JOUR. ECON. ENT. **29**: 217.

LeConte, John L. 1868. Appendix. *In* C. Zimmerman, Synopsis of the Scolytidae of America north of Mexico. Trans. Amer. Ent. Soc. **2**: 165, 167.

LeConte, John L. 1876. The Rhyncophora of America north of Mexico. Proc. Amer. Phil. Soc. **15**: 371, 373.

Leonard, M. D. 1928. A list of the insects of New York. Cornell Univ., Ag. Exp. Sta. Mem. **101**: 515.

Pechuman, L. L. 1937. An annotated list of insects found in the bark and wood of *Ulmus americana* L. in New York state. Bul. Brooklyn Ent. Soc. **32**: 13.

Swaine, J. M. 1918. Canadian bark-beetles. Part II. Canada Dept. Ag., Ent. Branch, Tech. Bul. **14**: 52.

SCIENTIFIC NOTES

A Cage for Rearing the Cheese Skipper, *Piophila casei* L.

Maggots of *Piophila casei* L., when mature, commonly leave the substrate on which they have been developing to pupate elsewhere. A cage especially designed to take advantage of this habit, and automatically collect the migrant skipper maggots, has proved so successful that the writer believes it may

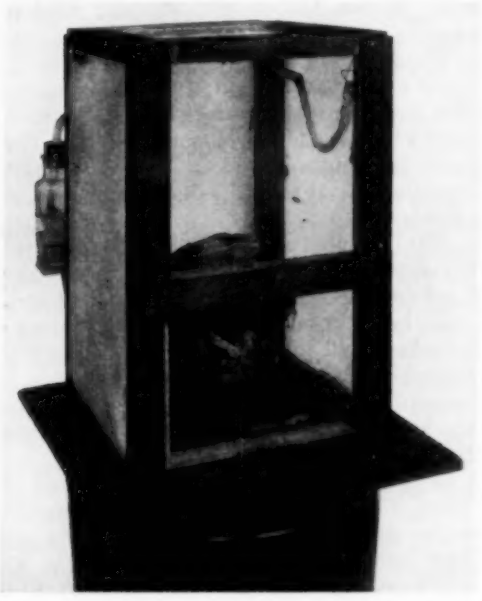

FIG. 1.—Complete cage, with glass panel and covering of lower half of front removed.

be useful in the handling of other Diptera, namely houseflies, etc., possessing habits similar to those of the cheese skipper.

The complete set-up, fig. 1, consists of an ordinary wood-frame cage supported by a masonite frame over a large metal wastebasket. The migrating skipper maggots pass through four elongate screen-covered openings in the floor of the cage and fall into the lower container, from which they are collected.

The cage proper (12×12×18 inches in height) is of wood-frame construction. The sides, back and the lower half of the front are covered with paraffined muslin called "glass cloth"; the top with celluloid; while the upper half of the front is provided with a removable glass panel fitted in sliding grooves. The wood floor possesses four elongated openings, one inch in width, arranged in the form of a square, fig. 2. Each opening is located parallel to and within one inch of one of the sides of the cage. The openings along the two sides of the cage are approximately 10 inches in length, while those at the front and the back are 7 inches in length. Copper wire screening (16-mesh) is stretched across the bottom of the cage and held securely along the margins of the four elongated openings by narrow wood strips. The wire screening must be of such a mesh that it will permit mature larvae to pass through the screening but will retain the adult flies. A 16-mesh screening proved satisfactory for the cheese skipper, *P. casei*, and a 12-mesh screening for the housefly, *Musca domestica* L.

The substrate container, bearing the smoked ham on which the skipper is reared, consists of the top half of a six-inch Petri dish three-fourths inch in depth. Too deep a container is conducive to pupation of the mature maggots within the container. The substrate container is supported above the floor of the cage, to prevent the larvae from pupating under the container, by three nails placed in the angles of an equilateral triangle of which the sides are one inch less in length than the diameter of the container. The container is prevented from sliding off the supports by four long finishing nails placed equidistant about the perimeter of the container.

Moisture within the cage is provided by means of the two long absorbent cotton wicks which pass into the cage through glass tubes arising from water bottles supported at the back outside corners of the cage.

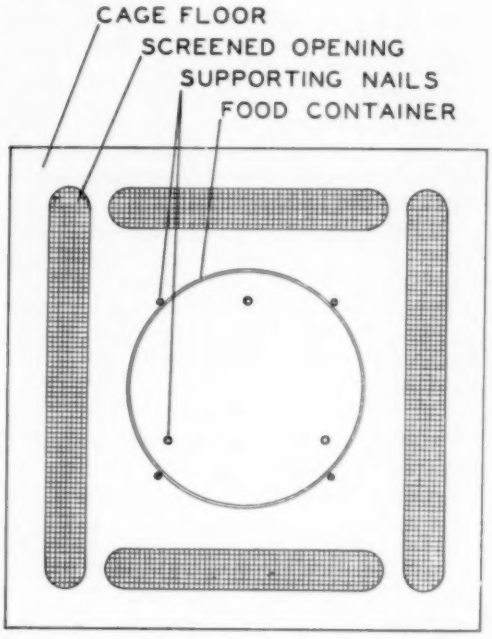

FIG. 2.—Floor plan of cage, showing location of openings, food container and nails supporting the container.

The cage rests on a masonite frame which not only serves to support the cage above the lower container but excludes the light from this container and aids in maintaining a relatively constant and high humidity.

A large metal wastebasket, having a top diameter of 15 inches and a height of 18 inches, constitutes the lower container into which the maggots fall. The inside of the container is coated with paraffin

to seal up all cracks and crevices into which maggots might crawl and pupate.

The maggots may be removed from this container, but if similar containers are available it will be found more convenient to replace the original container with another and permit the maggots which have been collected to pupate. A newspaper laid over the container serves to exclude dirt and light.

If, for any reason, it is found desirable to separate active maggots from a mixture of maggots and pupated material, this may be facilitated by placing the mixture on a horizontal glass plate supported several inches above the floor of the container. The maggots will crawl or "skip" off the plate.—5-10-38.

HERBERT A. CRANDELL, *Ohio State University, Columbus.*

The Furniture Beetle, *Anobium punctatum* DeG., in Washington

The furniture beetle, *Anobium punctatum* DeG., is a widely distributed pest in Europe, mining the timbers and woodwork of the walls of houses and other wood products. Outside of Europe it has been recorded from the Canary Islands and Madeira under the name of *striatum* Ol. by Wollaston (Coleop. Atlantidum, 1865, p. 227) and from Australia by Tillyard (*Insects of Australia and New Zealand*, 1926, p. 215) and other authors.

In North America it was first recorded from New Jersey under the name of *Hadrobregmus pumilus* by LeConte (Proc. Acad. Nat. Sci. Philad., 1865, p. 233). Under the name of *striatum* Ol., it was recorded by Fall (Trans. Amer. Ent Soc. XXXI, 1905, p. 181) from Massachusetts and Virginia and by Crosby (Ins. Pest Surv. Bul. 2, 1922, p. 149) as badly infesting the woodwork of a house in New York. Hungerford (Ins. Pest Surv. Bul. 5, 1925, p. 41) cited it as damaging books at Lawrence, Kan., but these books had recently been imported from Paris so that the species can hardly be considered to have become established on the basis of this record. Finally, Gibson and Twinn (Canada Dept. Ag. Bul. 112, 1931, p. 52) have noted it from the wood of a house in Nova Scotia. In view of these extremely scattered records, it is of considerable interest to note that the insect has now occurred in Washington, doing considerable damage to the woodwork of a house in Seattle.—5-9-38.

MELVILLE H. HATCH, *University of Washington, Seattle.*

Discussion of the Term "Derris Resinate"

On page 319 of the April issue of this journal there is a note by J. P. La Due of Riverside, Calif. This is an interesting note, but there is no such thing as derris resinate. A resinate is defined as a salt or ester of a resin acid. What Mr. La Due is talking about is derris extract.

It is true that some of the manufacturers of rotenone and derris extracts speak of derris resins and derris resinate. The term "derris resins" was used by Tattersfield and others 10 or 15 years ago, when less was known about the chemical composition of derris, to refer to some of the non-rotenone constituents of the root. While it is not incorrect to speak of derris resins inasmuch as the solid extract has a somewhat resinous appearance, it is incorrect to call this extract "derris resinate," because no salt, ester or other derivative has been formed. The term "derris extract" includes everything extractable from the plant by ether, acetone or other solvent and is the term that should be used in place of derris resinate.—5-9-38.

R. C. ROARK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Sulfur Nitride as a Possible Insecticide and Fungicide

During 1935, 1936 and 1937, sulfur nitride (S_4N_4, nitrogen sulfide)[1] was tested in the laboratory to determine if it had insecticidal properties (Franklin 1935). The Mexican bean beetle, *Epilachna varivestis* Muls. was used as the test insect, and the results showed that the pure compound was one-third as toxic to this insect as pure rotenone and twice as toxic as a commercial calcium arsenate or phenothiazine. Sulfur nitride, when used at a dilution of 1–10,000, retarded the growth of the common air spores *Penicillium* sp. and *Rhizopus* sp.

A laboratory preparation containing 30 per cent of sulfur nitride caused no visible plant injury when ground with an equal weight of talc or bentonite and applied to bean foliage at the rate of 1½ pounds of the mixture (0.2 pound of pure sulfur nitride) to 50 gallons of water.

Since this chemical is not generally known its characteristics are given. Sulfur nitride exists as orange-red crystals melting at 178 degrees to 180 degrees C. It is insoluble in water but soluble in a few organic solvents, such as benzene, carbon tetrachloride, kerosene, etc., and is also soluble in liquid ammonia. Molecular-weight determinations indicate the formula S_4N_4, but the exact structure of the compound is not known. Practically all the methods proposed for its preparation involve approximately the following reaction:

$$16\ NH_3 + 6\ S_2Cl_2 = 12\ NH_4Cl + S_4N_4 + 8S.$$

This reaction is customarily carried out by passing gaseous ammonia into a solution of sulfur monochloride in some inert solvent, such as chloroform, benzene or ether. Unless the process is controlled, the presence of chlorine compounds of sulfur and nitrogen formed during the reaction reduces the yield below the theoretical. The ammonium chloride may be removed with water and the remaining mixture has been found by analysis to contain approximately 30 per cent of sulfur nitride. This material may be reduced to a suitable impalpable powder by grinding with a diluent such as talc or bentonite (1–1). Grinding may be unnecessary if the nitride is dissolved in a volatile solvent before being incorporated in the diluent. The product may be further diluted with a suitable carrier and applied as a dust, or it may be used directly in water as a spray.

Pure sulfur nitride is practically odorless, but most preparations have a distinctly acrid, musty odor which is due to the presence of an impurity. This characteristic odor can be detected on plant foliage several days after the application.

The fact that pure sulfure nitride has a tendency to detonate when struck with a hammer would seem to indicate a serious hazard in the use of the ma-

[1] U. S. Patent No. 2,101,645, granted December 7, 1937, to Robert A. Fulton and W. Conard Fernelius. The material used in these tests was prepared by W. C. Fernelius of Ohio State University, Columbus.

terial as an insecticide. The mixture of sulfur nitride and sulfur formed in the above-mentioned reaction does not detonate when struck with a hammer or when ground with talc or bentonite.—5-18-38.

ROBERT A. FULTON, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

LITERATURE CITED

Franklin, E. C. 1935. The nitrogen system of compounds. A.S.C. Monograph Series **68**: 174–5. New York.

Variation in the Susceptibility of Brambles to the Red-Necked Cane Borer, *Agrilus ruficollis* (F.)

The red-necked cane borer is a major pest on brambles in Oklahoma. The injury is caused by the larva girdling the cane, usually near the base, producing a gall. Some canes may have several galls. Beyond the gall, the cane usually dies and rarely produces any fruit. This is referred to as "dieback."

There is a wide variation in the per cent of infested canes and various varieties of brambles as indicated by the presence of visible galls, table 1. These counts were made in the variety test block of the Horticulture Department at the Perkins experimental farm, March 18, 1938.

In many cases a resistant variety was situated between susceptible varieties. The native blackberry vines were about 50 yards from some of the most susceptible varieties, such as McDonald and Early Wonder.

There seems to be a preference for the prostrate and semiprostrate varieties, although the extremely small cane, prostrate variety, Advance, had no infestation.—5-18-38.

EPHRAIM HIXSON, *Oklahoma Agricultural and Mechanical College, Stillwater.*

Paratrioza cockerelli (Sulc.) in Oklahoma

An outbreak of the potato psyllid, *Paratrioza cockerelli* (Sulc.), occurred in the greenhouse planting of tomatoes at the Oklahoma Agricultural and Mechanical College, Stillwater. The tomatoes were planted in the fall of 1937, but the infestation of psyllids was not noticed until March, 1938. The species was determined by C. F. W. Muesebeck of the U. S. Bureau of Entomology and Plant Quarantine. The psyllids were readily brought under control with lime sulfur, 1–45, as recommended by the Colorado Experiment Station. This spray left a residue on the tomato fruits that was most difficult to remove either by wiping with a dry or wet cloth.—5-18-38.

EPHRAIM HIXSON, *Oklahoma Agricultural and Mechanical College, Stillwater.*

The Common Red Spider and Carnation Rust

Observations of the common red spider, *Tetranychus telarius* (L.), on carnation plants prior to setting up experiments to determine the part these mites play in the dissemination of the carnation rust fungus, *Uromyces caryophyllinus* (Schr.) Wint., showed (1) that common red spiders usually enter the rust pustules on carnation leaves and (2) that common red spiders may carry the uredospores of carnation rust.

In the first lot of 97 common red spiders taken from carnation leaves having rust pustules, 17 carried uredospores of carnation rust. In the second lot of 77 mites, 23 carried uredospores. All of the mites were examined separately under the microscope in a drop of clean water.

As indicated above, this work will be continued in an endeavor to find out more facts about the com-

Table 1.—Infestation of various varieties of blackberry and dewberry by the red-necked cane borer, *Agrilus ruficollis* (F.) at Perkins, Okla., 1937.

Variety	Number of Canes		Per Cent Infested	Growth Habit
	Examined	Infested		
1. Early Wonder (Row 1)	100	72	72	Semiprostrate
2. Early Wonder (Row 2)	100	69	69	Semiprostrate
3. McDonald	100	68	68	Semiprostrate
4. Haupt	50	30	60	Semiprostrate
5. Brainerd	29	12	41	Spreading
6. Robinson	100	28	28	Spreading
7. Rathburn	200	50	25	Spreading
8. Macatawa	96	24	25	Upright
9. Best of All	100	9	9	Upright
10. Native in nearby woods	50	2	4	Upright
11. Blower	200	6	3	Upright
12. Ozark Beauty	100	3	3	Upright
13. Mersereau	200	4	2	Upright
14. Early Harvest	500	0	0	Upright
15. Youngberry (Phenomenal×Mayes)	300	94	31	Prostrate
16. Lucretia	100	12	12	Prostrate
17. Austin Mayes	100	5	5	Prostrate
18. Advance	100	0	0	Prostrate

mon red spider in connection with the carnation rust fungus.

The mites were identified by E. A. McGregor of the U. S. Department of Agriculture.—6-8-38.

DEAN ASQUITH, *Massachusetts State College, Amherst.*

Tarsonemus spp. Attacking Mushrooms

During the seasons of 1936 and 1937, two species of mites of the genus *Tarsonemus* were found attacking the crop in commercial mushroom houses.

The first record is from Beltsville, Md., where *Tarsonemus floricolus* C. & F. was found in small numbers in an experimental mushroom house early in 1936, and a note concerning this finding was published in the Insect Pest Survey Bulletin, Vol. 16 (8): 376, 1936, and Vol. 17 (10): 632, 1937.

This mite was again observed in a mushroom house near Chicago in the spring of 1937, occurring in enormous numbers and severely damaging the crop. Another *Tarsonemus* of an undescribed species was doing damage in a few commercial mushroom houses in the mushroom-growing section of Pennsylvania during the fall of 1936 and the spring and fall of 1937.

In this connection it is of interest to record here the fact that Floyd F. Smith collected *T. floricolus* from Japanese iris at Brooklyn, N. Y., in 1934, which may be the first record of this species in America.—6-24-38.

A. C. DAVIS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Notes on Wettable Sulfurs*

Wettable sulfurs have come into quite general use for peach and other stone fruits in various parts of the country. Many excellent forms have been developed which differ in (1) the percentage of sulfur, (2) the adulterants or fillers and (3) the wetting agents. In the newer types of wettable sulfurs, the adulterants have been cut to a minimum and the percentage of sulfur raised, in some, as high as 98½ per cent. In all cases the wetting agent constitutes a very small percentage of the mixture.

It is evident, from a glance at table 1, that there is remarkable inconsistency in the amount of sulfur applied per hundred gallons of spray solution when used according to recommendations. The amount of sulfur per hundred gallons ranges from 1.8 to 16 pounds. This suggests two questions: (1) how much sulfur is essential to handle the problems of peach spraying and (2) can the amount of sulfur in self-boiled lime sulfur and dry mix be reduced without affecting its toxicity? No attempt is made to answer these questions but merely to emphasize the discrepancy existing in the use of various types of wettable sulfurs.

For several years considerable foliage injury has been noted in areas where heavy applications of self-boiled lime sulfur has been used on peach. This explains, in a large measure, why many growers have shifted from self-boiled lime sulfur to various forms of wettable sulfur. The injury was emphasized when 2 per cent summer oil emulsion was added to self-boiled lime sulfur and the two applied together. The burning was apparently due to excessive amounts of sulfur retained by the oil on the foliage. Injury of this sort was cited by Frost (1936).

Summer oil emulsions and soaps have a definite place in the control of summer broods of European red mite, *Paratetranychus pilosus* (G.&F.), and peach lecanium, *Eulecanium nigrofasciatum* Perg.

The problem of combining sulfur with oil emulsions must be considered. Frost (1937) has shown that bentonite sulfur combines well with oil emulsions and can be used on peach without injury after July 1. On the other hand he has pointed out that certain wettable sulfurs are incompatible with oil emulsions, producing sticky combinations that clog the screen of the spray machine. The wetting agent should be considered when oils are to be combined with summer oil emulsions.—6-15-38.

S. W. FROST, *The Pennsylvania State College.*

* Authorized for publication, August 8, 1938, as paper No. 845 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

LITERATURE CITED

Frost, S. W. 1936. Soap washes and oil emulsions as summer sprays for peach. JOUR. ECON. ENT. 29(2): 364–9.

Frost, S. W. 1937. Tests with summer oil emulsions on peach. JOUR. ECON. ENT. 30(4): 658–63.

Table 1.—Comparisions of wettable sulfurs as recommended for peach.

WETTABLE SULFUR	MANUFACTURER	PER CENT ACTUAL SULFUR	RECOMMENDED DILUTION LBS. PER 100 GALS.	ACTUAL SULFUR PER 100 GALS. OF SPRAY
Kolofog	Niagara Spray Chem. Co.	30.0	6	1.8
Koloform	Niagara Spray Chem. Co.	54.0	10	5.4
Flotation, paste	Coppers	50.0	10	5.0
Dritomic	General Chem. Co.	90.0	5	4.5
Mike	Dow Chem. Co.	95.0	5	4.7
Sulculoid	Ansbaugher	95.0	6	5.7
Mulsoid	Sherwin-Williams	95.0	4 to 5	3.8 to 4.7
Microscopic	Mechlings	95.0	4 to 5	3.8 to 4.7
Magnetic	National Sulfur Co.	98.5	4 to 6	3.9 to 5.9
Sulfron	DuPont	95.0	6 to 8	5.7 to 7.6
Self boiled lime sulfur	Home Mix	50.0	32	16.0
Dry mix	Home Mix	64.0	25	16.0

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 31 August 1938 No. 4

Award for Meritorious Research

WORTHY precedent is found in many fields for the decision of the Eastern Branch of the American Association of Economic Entomologists to make an annual award to one of its members for meritorious research in the field of economic entomology. The yearly awards of the American Association for the Advancement of Science are known to research workers in all branches of science. Many other scientific and non-scientific organizations, national and sectional, make annual awards, among them the American Institute of Electrical Engineers, the American Chemical Society, the Society of Chemical Industry, the National Institute of Arts and Letters, the Chemical Society of Washington and the American Association of Physics Teachers.

Such awards satisfy the very human desire for recognition of work well done. They provide an incentive for thoughtful, original and thorough research. Not only do they tend to improve the work within the field by honoring men still active; they dignify the research in that field by calling it to the attention of other scientific groups and of laymen.

The recently announced annual prize of the Eastern Branch is to be awarded to the member of that group in good standing who at the yearly meeting presents the paper which in the opinion of a committee of three judges is the year's "best contribution to the Science of Economic Entomology."

Consisting of a medal and $75 in cash, the first annual award will be presented to the author of a paper read at the Eastern Branch meeting this fall. The ceremony of presentation will take place at the annual meeting of the American Association of Economic Entomologists in Richmond, the award being made by the President of the Association in the name of the Eastern Branch. In the event that more than one name appears as the author of the paper selected by the judges, a medal will be presented to each of the authors, and the cash prize will be divided equally.

The paper winning the award will be published in the JOURNAL OF ECONOMIC ENTOMOLOGY with the other papers of the Eastern Branch, accompanied by the statement: "Awarded the Annual Medal of the Eastern Branch, American Association of Economic Entomology, for the year 1938."

Members of the Committee on Annual Award appointed by V. I. Safro, Chairman of the Eastern Branch, are C. H. Hadley, Chairman, P. J. Chapman and William Moore. The Committee has already selected a design for the medal, and the action of the Eastern Branch, November 19, 1937, gives to this Committee full authority to carry out its purpose.

Competing papers must be submitted to H. B. Weiss, Secretary-Treasurer of the Eastern Branch, 1 West State Street, Trenton, N. J., prior to or at the time for submission of papers for the annual meeting of the Eastern Branch. Preparation of papers must conform to certain requirements laid down by the Committee. Full details of these requirements may be obtained from Dr. Weiss.

An interesting provision of the award is that "the Judges shall give consideration to form, style, and correctness of language, clarity of presentation and interpretation of data, and soundness of conclusions drawn, as well as the importance of the paper as a contribution to the Science of Economic Entomology." This provision implies that the Committee recognizes the value of interpretation. Scientific research, whatever its potential value, can benefit humanity only in the degree to which it is adequately interpreted.

The action of the Eastern Branch in establishing an annual award for entomological research is a sign of vision and progressiveness. It is an action that might well be emulated by the national organization, the American Association of Economic Entomologists.—7-16-38.

REVIEWS

Insect Enemies of Western Forests, by F. P. Keen. 1938. 208 pp. illus. U.S.D.A. Misc. Pub. No. 273.

Keen's recent bulletin, *Insect Enemies of Western Forests,* is a most welcome addition to forest entomological literature. Hitherto, it has been difficult to obtain authentic and adequate information from literature concerning many important western forest species. The publications dealing with specific insects or groups have been all too few, and the more comprehensive publications have been inadequate, chiefly because of spatial limitations.

In his bulletin, Keen has succeeded in condensing a tremendous amount of information into a small space by selecting carefully both the species to be discussed and the details concerning each that should be emphasized. In this, his long experience in the western forests, during which time he has been in constant contact with field problems, has evidently been helpful.

By way of introduction, he discusses briefly the kinds of damage caused by forest insects, the importance of this injury to forest management and the signs of the various kinds of insect injury that forest officers should recognize. Then follows a discussion of specific insects arranged according to tree age, class and character of product attacked.

A valuable feature of this publication, especially for those not very well versed in forest entomology, are the diagnostic keys of injury. These are based on the character of damage and indicate the kind of injury caused by the various groups and species. Also, in view of the economic importance of forest range in the western states, the inclusion of a section on insects injurious to range plants will prove useful. This section might have been expanded somewhat to good advantage.

The final 30 pages are devoted to an excellent discussion of insect control. Naturally, a considerable proportion of this section is devoted to the control of bark beetles, because of their importance in mature western forests.

It is not often that a reviewer examines a publication which so nearly satisfies all requirements as does this bulletin. One might wish that some species had been more fully discussed, but, when the purpose of the publication is considered, this criticism is not serious.

Because of its excellent arrangement and the clear presentation of well-selected materials, this bulletin should be well received by entomologists, foresters and others interested in conservation of our timber resources.—6-17-38.

S. A. Graham, *University of Michigan, Ann Arbor.*

Wood Preservation, by George M. Hunt and George A. Garratt. 1938. Cloth. ix+457 pp. 108 figs. McGraw-Hill, New York. $5.00.

This work is a summary of the entire subject of wood preservation, including agencies of wood deterioration, preservatives, processes, equipment and economic aspects of preservative treatment. It brings together in a single volume information which has previously been available only in scattered publications. The authors are well qualified to discuss the subject. Dr. Hunt is in charge of the section of wood preservation, U. S. Forest Products Laboratory, and Dr. Garratt is Associate Professor of Forest Products at the Yale School of Forestry.

The agencies of wood deterioration are discussed fully, including wood rots, termites, *Lyctus* beetles, carpenter ants, *Teredo, Limnoria, Chelura,* fire, mechanical wear and weathering. While the main emphasis has been placed on the proper use of treated wood, other methods of control and prevention are adequately discussed.

The chapters on preservatives, processes and equipment contain an enormous amount of technical information which is presented in a very clear and concise style. Proprietary preservatives are listed by name with an adequate statement regarding composition. Any established facts regarding the effectiveness of these materials are included.

The chief value of this book to entomologists is its authentic information on preservatives and processes. Little is said about the method of treatment of timber in place, a system used in termite control. However, the discussions of preparation of timber for treatment and treating processes emphasize the difficulty of proper treatment of wood even under the most favorable conditions. The volume is especially valuable to entomologists interested in termite control.—5-23-38.

Neely Turner, *Connecticut Agricultural Experiment Station, New Haven.*

OBITUARY

George Ringo Wilson 1885-1938

With the death in Alameda, June 11, 1938, of George R. Wilson, Associate Quarantine Entomologist with the Bureau of Plant Quarantine, California State Department of Agriculture, and Collaborator with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture in San Francisco, there passed an entomologist of rare ability, who, due to his innate modesty was possibly not so widely known to the outside world as he should have been, but whose loss will be keenly felt by those for whom he labored and by those who knew him personally as a co-worker.

He was born in Mulberry, Kan., January 11, 1885, moving to California a few years later. His normal early interest in insects was continued later, culminating in his receiving the degree of Bachelor of Science in Agriculture at the University of California in 1910, with his major in entomology. Immediately after graduating from college, he returned to his former home in southern California and became associated with the office of the Horticultural Commissioner of Riverside County as Entomologist and Inspector. While he qualified himself for the position of County Horticultural Commissioner in that county, he refused appointment, preferring to continue his entomological work. In 1917 he saw an opportunity to follow his inclinations further and accepted a position as Quarantine Inspector with

the State Department of Agriculture at the port of San Francisco. Here also he later qualified himself for appointment to Senior Inspector in charge of the port, but again when opportunity offered shunned the administrative duties in favor of his entomological work, which he continued until his death.

Due to the fact that San Francisco until recently was one of the only two authorized ports of entry for plant material from foreign countries under permit, a tremendous number of intercepted insects from all parts of the world passed through his hands for determination. The opportunities were abundant but demanding; in fact, so demanding that he found little time to record and publish his findings, with the result that a vast fund of information on world species, distribution and hosts, which he had at his finger tips, passed with him. He possessed an uncanny entomological sense which allowed him to place innumerable intercepted specimens immediately to a point which even the resources of the National Museum could carry little further.

His personal interests lay in the Coccidae, and he found the time to gather together both a private and an official collection which in number of species is exceeded by few others in this country. He had in preparation at the time of his death a manuscript covering his work in this group, which it is hoped may be in such shape that it can be offered for publication at a later date.

He was a member of the Del Rey Fraternity, in which he maintained an active interest; also of the American Association of Economic Entomologists, the Entomological Society and the Pacific Coast Entomological Society. He was particularly active in the last organization, never missing a meeting or a field trip.

Quiet, reserved, keenly interested in matters outside his own field, always helpful where opportunity offered, he will be deeply missed and always remembered by his friends and co-workers.—6-24-38.

H. M. ARMITAGE, *California State Department of Agriculture.*

CURRENT NOTES

OTTAWA A.A.A.S. MEETING, 1938

The 102nd meeting of the American Association for the Advancement of Science was held in Ottawa, Canada, June 27 through July 2. In entomology, three general sessions and a symposium were held under the auspices of the American Association of Economic Entomologists, the Entomological Society of America and the Entomological Society of Ontario. Dr. Arthur Gibson was chairman of the local committee that organized the program; C. R. Twinn was secretary.

Twenty-five papers were presented, and abstracts of these were distributed at the meetings, together with mimeographed copies of the program. Following the sessions, two field trips of interest to entomologists and others were arranged, one to the Petawawa Forest Experimental Station and the other to the Mer Bleu.

Many of the papers presented were of high caliber, according to the secretary. The sessions were reasonably well attended and, in general, the meetings were a great success. Seventy-five persons interested in entomology, of whom more than one-third were from the United States, registered at the sessions. This number is exclusive of the foresters, forest pathologists and representatives of the forest industry, who attended the symposium on forest insects.

COTTON STATES BRANCH MEETING

The 1939 meeting of the Cotton States Branch, American Association of Economic Entomologists, will be held at Tampa, Fla., during the early spring. The dates and convention headquarters in Tampa will be selected at an early date.

The Newell Entomological Society of the University of Florida is to serve as official host. Cosponsors are the Florida Entomological Society, the Florida Institute of Agricultural Research, the Florida Horticultural Society, the Florida College of Agriculture, the Florida Experimental Station, the Florida State Plant Board and the Tampa Chamber of Commerce.

The Florida Entomological Society has donated funds to aid in preparations for the meeting.

The Florida Institute of Agricultural Research is to be in entire charge of the entertainment during the annual banquet.

HUGH GLASGOW PROMOTED

Dr. Hugh Glasgow has been named Head of the Division of Entomology, New York State Agricultural Experiment Station, Geneva, effective July 1, to fill the vacancy created by the promotion of Prof. P. J. Parrott to the position of Station Director.

Dr. Glasgow first entered the employ of the Station as an associate in the Entomology Division in 1914, following soon after his graduation from the University of Illinois. With the inauguration in 1925 of special investigations of insect pests of canning crops, including both fruits and vegetables, he devoted his entire time to the study of canning crop pests, and in 1929 was promoted to the position of chief in research in entomology

ENTOMOLOGISTS TO INTERNATIONAL CONGRESS

Among the entomologists leaving for the Berlin meeting of the International Congress of Entomology are Dr. P. P. Baiby, Dr. J. C. Bradley, Dr. O. A. Johannsen, Dr. Edith M. Patch, Curtis W. Sabrosky, Walter Ebeling and Miss Ester C. Hende. The group includes about 20 persons and is under the personal supervision of Dr. Bradley. Points in a dozen countries will be visited on the lengthy tour.

Dr. Arthur Gibson has been appointed by President J. J. Davis a delegate from the American Association of Economic Entomologists to the International Congress. H. L. Sweetman is alternate. Dr. Johannsen is the delegate from the Entomological Society of America.

HONORARY DEGREES

The University of North Carolina conferred the degree of LL.D. upon C. S. Brimley of the Division of Entomology, North Carolina Department of Agriculture, at its commencement on June 7, 1938.

Louisiana State University conferred the honor-

ary degree of doctor of science on Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine, United Srates Department of Agriculture, May 30.

PURDUE NEWS

Dr. H. O. Deay has been advanced from Assistant Professor of Entomology at Purdue University to Associate Professor. George E. Gould has been advanced from Assistant in Entomology of the Purdue University Agricultural Experiment Station to Associate in Entomology.

Prof. J. J. Davis addressed the National Association of Insecticide and Disinfectant Manufacturers at their semiannual meeting at Lake Wawasee, Ind., June 15, on the subject, "The Future of Household Insecticides on the Farm."

The Purdue University Agricultural Experiment Station is this year continuing a survey of forest and forest nursery insects of Indiana, which was begun in 1937. Dr. B. E. Montgomery is conducting the survey.

PEST CONTROL MEETING

The National Pest Control Association will hold its annual convention at Omaha, Nebr., October 24–26. The Hotel Fontenelle will be the convention headquarters. Many prominent entomologists will participate in the meetings. Prof. J. J. Davis of Purdue University will direct the clinics.

VISITING ENTOMOLOGIST

Dr. Stanley F. Bailey of the Department of Entomology of the University of California, stopped at Urbana, Ill., on July 6 to look over the University of Illinois and the Illinois Natural History Survey collections. Dr. Bailey was on his way to Amherst, Mass., where he hoped to study collections of Thysanoptera. Before his arrival at Urbana, he had stopped at Kansas State College, the University of Kansas and the University of Missouri.

OHIO ENTOMOLOGISTS IN ILLINOIS

Two Ohio entomologists are working with the Illinois Natural History Survey, Urbana, during the summer and fall months. Dr. D. M. DeLong of Ohio State University, Columbus, will devote the month of September to a continuation of his studies of the Cicadellidae of Illinois, begun four years ago. M. W. Boesel of Miami University, Oxford, is beginning a study of the state's Ceratopogoninae. The latter investigation is a segment of a larger project involving all the blood-sucking insects of Illinois.

NATURAL RESOURCES BUILDING

Plans for the first unit of a five-story concrete, hollow tile and brick structure of Georgian architecture to be known as the State Natural Resources Building are brought nearer to completion with a recent PWA grant of $245,454, announced in July. This sum is in addition to $300,000 already appropriated by the state of Illinois. The building is to be built on the University of Illinois campus. Headquarters and most of the sections of the Illinois Natural History Survey, including those in entomology, will be located in the new structure.

PACIFIC SLOPE BRANCH MEETING

The Pacific Slope Branch of the American Association of Economic Entomologists held its twenty-third annual meeting, June 23 and 24. During the sessions 22 papers were presented. These dealt with a wide range of entomological subjects including insect toxicology and evolution of field data. Total attendance at the meeting was 71.

The entomologists' dinner was held Thursday evening, when the members were addressed by J. J. Davis, President of the American Association of Economic Entomologists, and J. A. Hyslop of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Officers elected for 1938 were, Chairman, R. H. Smith, University of California, 405 Hilgard Avenue, Los Angeles; Vice Chairman, B. G. Thompson, 303 Agricultural Hall, Oregon State College, Corvallis; Secretary-Treasurer, J. F. Lamiman, University of California, Davis.

ENGLISH ENTOMOLOGIST IN THE UNITED STATES

J. A. Downes of London, England, specializing in insect ecology at the University of California under Prof. W. B. Harms, spent two days, July 22–23, in Urbana, Ill., studying the entomological activities of the Illinois Natural History Survey and the University of Illinois.

A graduate of the Imperial College of Science, University of London, Mr. Downes was on the way back to California for his second year of study at Berkeley after a tour which included the Bureau of Entomology and Plant Quarantine and the National Museum, Washington, the Museum of Comparative Zoology at Harvard, and Cornell University. He planned to stop at Iowa State College, Ames, and Montana State College, Bozeman, on his trip back to the West Coast.

Mr. Downes is in the United States studying on a Commonwealth Fund Fellowship, which is comparable to a Rhodes Scholarship. The English student on a Commonwealth Fund Fellowship, however, has a certain choice of institutions, whereas the American student on a Rhodes Scholarship must attend Oxford. Mr. Downes' first choice was the University of California. The Commonwealth Fund was established by the Harkness Foundation.

JOINT SYMPOSIUM AT ANNUAL MEETING

With the Entomological Society of America and the Ecological Society of America, the American Association of Economic Entomologists has arranged a joint symposium for the annual meeting at Richmond, Va., on the general topic "Insect Populations." The symposium is scheduled for the Roof Garden of the John Marshall Hotel on the afternoon of December 27. Dr. V. E. Shelford of the University of Illinois will preside.

The detailed program is as follows: "Insect Population Problems in Relation to Insect Outbreaks," Royal H. Chapman, Pineapple Producers' Experiment Station, Honolulu; "Population Studies of Soil Insects," Kenneth M. King, Dominion Entomological Laboratory, Saskatoon, Sask.; "Populations of Social Insects," Alfred E. Emerson, Department of Zoology, University of Chicago; "Forest Insect Populations," Samuel A. Graham, School of Forestry and Conservation, University of Michigan; "Insect Populations in Relation to Biological Control," Harry S. Smith, Citrus Experiment Station, University of California, Riverside.

Program for the Annual Meeting

At the annual meeting of the Publications Committee held at the time of the last meeting of the American Association of Economic Entomologists at Indianapolis, December 27–31, 1937, it was decided that henceforth the program for the annual meeting will be issued separately, instead of with the December issue of the JOURNAL OF ECONOMIC ENTOMOLOGY. Publication of the program in the JOURNAL has in the past tended to delay issue of the December number.

Members of the Association who have in mind preparation of papers for the next annual meeting are asked by officers of the organization to see that titles, brief abstracts, information as to length of time of presentation and other pertinent data are presented to the Program Committee in ample time to prevent delay in the printing of the program.

As usual, forms for submitting this information will be mailed to members at an early date.

The Program Committee consists of the following: W. P. Flint, Chairman, Illinois Natural History Survey, Urbana, Ill.; D. L. Van Dine, Bureau of Entomology and Plant Quarantine, Washington, D.C.; and George A. Dean, Kansas State College, Manhattan, Kan.

Reservations for Annual Meeting

Early reservation of rooms for the December meeting of the American Association of Economic Entomologists is imperative, owing to the limited accommodations. The Hotel John Marshall in Richmond will be the headquarters of the entomologists. This hotel has the following rooms available:

Number of Rooms	*Prices*
40 single or double	$3.50—5.50
40 single or double	4.00—6.00
20 single or double	5.00—7.00
40 twin beds	6.00
60 twin beds	7.00
50 twin beds	8.00

Reservations should be made through Leonard K. Baber, Director of Advertising and Sales, Richmond Hotels, Richmond, Virginia.

According to the Secretary of the Association, there is going to be a tremendous paucity of accommodations at the better hotels. He urges all members who contemplate attending the meeting in December to make reservations at once.

CLASSIFIED

Advertisements of commodities for sale or exchange or services will be entered at 50 cents per issue or $2 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. Send all notices and cash in advance to Ernest N. Cory, College Park, Md., by the 15th of the month preceding publication.

FOR SALE AT A BARGAIN. JOURNAL OF ECONOMIC ENTOMOLOGY, Vols. 13, 14, 15 and 17 to 23 incl., complete, $32. *Annals* Ent. Soc. Amer., Vols. 14 to 24 incl., complete, $35. *Phytopathology*, Vols. 14 to 20 incl., complete, $23. U.S.D.A. Tech. Buls. 1 to 200, bd. in 5 vols., the lot, $16. U. S. Nat. Mus. Entomological Proceedings, Vols. 57 to 78, bd. in 5 vols., the lot, $14. Indiana State Entomological Anl. Repts. 1 to 6 complete, $4. N.Y. State Ent. Anl. Repts. 1904-05, 1907-08, 1910-11 and 1912-13, unbound, the lot, $2. N.Y. Col. Forestry, Syracuse, Tech. Buls. 1 to 34 incl., Buls. 1 to 16 incl., Circulars 1 to 46 incl. and Leaflets 1 to 3, the lot, $10. *Scientific Monthly*, Vols. 23 to 26 incl. and 29 to 33 incl., the lot, $12.50. With very few exceptions these volumes are beautifully and uniformly bound in half-morocco, with gold titles. Prices, F.O.B. New Orleans. Write Prof. G. Wm. Nott, 1410 Jackson Ave., New Orleans, La.

ASSISTANT to the Editor of the JOURNAL (2 years) seeks change of full-time employment. Now printing production man for eastern land-grant college; formerly editor midwestern state research division (6 years). College, university, experiment station, or science publications work preferred; able also to handle publicity, advertising, or general book and periodical editing. Carroll Chouinard, Box 642, State College, Pa.

FOR EXCHANGE: JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 8, complete, bound; Vol. 7, complete; Vol. 15, complete; Vol. 14, Nos. 5 and 6; Vol. 16, No. 1. Volumes and numbers desired: Vols. 1, 2, 3 and 4, complete; Vol. 5, Nos. 1, 2 and 3; Vol. 11, No. 6, Vol. 16, No. 8. R. R. Parker, U.S.P.H.S., Hamilton, Montana.

FOR SALE: JOURNAL OF ECONOMIC ENTOMOLOGY Volumes 1 to 29, lacking seven numbers in Vols. 15 and 16. Annals of the Entomological Society of America, 1910 to 1921 complete, also 1924 to 1934 complete. U. S. D. A. Bureau of Entomology and Plant Quarantine, part of old series bulletins, and new series complete; technical series bulletins complete, also circulars complete. North American Fauna. Experiment Station Record 1905 to 1919. Some National Museum separates and geological survey bulletins; many state publications. Write W. H. Goodwin, North Lima, Ohio.

FOR SALE AT A BARGAIN. JOURNAL OF ECONOMIC ENTOMOLOGY Volumes 1 to 8, inclusive (complete Vol. 1, No. 6), unbound, $26.

Annals of the Entomological Society of America, Volumes 1 to 6 complete unbound, $20 F.O.B. Washington, D.C. Some issues very rare. From library of the late Professor F. M. Webster. Write H. L. Webster, 2605 Monroe Street N.E., Washington, D.C.

DICTIONARY of Entomological terms: In preparation. Authors invite correspondence relative thereto and request new words as well as references to articles citing terms or dealing in any way with nomenclature. Parker & Smith, 61 Avenue Alfred Belmontet, St. Cloud, S. & O., France.

FOR SALE from the library of the late W. E. Rumsey: Complete sets—JOURNAL OF ECONOMIC ENTOMOLOGY, first 19 vols. bound in half leather; *Annals*, first 19 vols. bound in buckram; Experiment Station Record, first 54 vols. bound in half leather. Many other publications and bulletins of entomological interest collected over a period of 50 years. Also Contributions from the United States National Herbarium, complete except for No. 1 of Vol. 1. For details write Neal O. Rumsey or Dr. L. M. Peairs, Morgantown, W.Va.

Index to Advertisers

American Association of Economic Entomologists, Collége Park, Md. vi
Carbide and Carbon Chemicals Corporation, New York City viii
Chipman Chemical Company, Inc., Bound Brook, N.J. v
Hardie Mfg. Company, The, Hudson, Mich. v
Journal of Economic Entomology, College Park, Md. vii
McCormick Sales Co., The, Baltimore, Md. ix
Nico-Dust Manufacturing Co., Los Angeles, Calif. iv
S. B. Penick and Company, New York City iv

ROTENONE - PYRETHRUM

DERRIS ROOT (Derris Elliptica) and **TIMBO** (Lonchocarpus Urucu) : Finely powdered standardized to assay 4% or 5% rotenone, plus the other ether extractives.

Also liquid, soft and powdered extracts of Derris.

ROTENONE CRYSTALS: Chemically pure and 90% technical.

PYRETHRUM FLOWERS: Whole—granulated for extraction—finely powdered for dusting—with definite pyrethrins content.

PYREFUME: Concentrated extract of pyrethrum flowers, in Petroleum Distillate, Pine Oil or Alcohol.

S. B. PENICK AND COMPANY
132 Nassau Street, New York City

Largest Botanical Drug Firm in the World

RELIABLE INSECTICIDES

A dependable source of supply of reliable insecticides for buyers in the western half of the United States. For more than 20 years, manufacturers and distributors of dusts, sprays, dusting machines, spreaders and agricultural chemicals.

Manufacturers of genuine *Nico-Dust*, the original nicotine dust. Importers, millers and extractors of pyrethrum and rotenone products. We have the only complete plant on the Pacific coast for milling and extracting botanical plants. Rotenone and pyrethrum powders, extracts, sprays and dusts.

A complete line of vegetable dusts made from standard insecticides such as cryolite, copper, arsenicals, rotenone, pyrethrum, nicotine, etc.

Exclusive Distributors for the famous *Grun Knapsack Duster.*
Distributors for *Root* power and hand guns.

All products manufactured and tested under careful chemical and entomological supervision.

We will be glad to submit samples and we welcome inquiries.

NICO-DUST MANUFACTURING CO.
2412 East 57th St. Los Angeles, Calif.

Add up the figures after five or ten years to know the actual cost of a sprayer. Hardie sprayers cost less to own and operate any way you figure it—number of gallons pumped per year or period of years, number of trees sprayed, number of acres sprayed with a given pump size.

The smaller Hardies are built just like the big Hardies and perform with equal efficiency and economy within their ratings. Both large and small growers get the best there is when they buy a Hardie. Let us send you our 1938 catalog for your files.

THE HARDIE MFG. COMPANY, HUDSON, MICHIGAN

Branch Factories, Sales and Service Offices: Portland, Ore., Los Angeles, Calif., Brockport, N.Y.
Export Department, Detroit, Mich.

HARDIE DEPENDABLE SPRAYERS

CUBOR

Dusts and Spray

Non-Arsenical Rotenone Insecticides

STABILIZED. Cubor Insecticides are made from choice rotenone-bearing roots of known chemical analysis. Each product is chemically stabilized by being impregnated with a preservative which retards normal decomposition, preserves toxicity, adds to repellent value and improves adhesiveness.

SAMPLES AVAILABLE in the following strengths: CUBOR DUST "50" (.50% rotenone); CUBOR DUST "75" (.75% rotenone); CUBOR SULPHUR DUST (.75% rotenone); CUBOR DUST 100 (1% rotenone); CUBOR DUST 100 TT (1% rotenone plus at least 2½% other associated toxic ingredients on a tobacco dust base); CUBOR SPRAY POWDER (2½% rotenone plus at least 6¼% other associated toxic ingredients). Send requests for samples to Research Department.

CHIPMAN CHEMICAL COMPANY, INC.
BOUND BROOK, N. J.

INDEX TO THE LITERATURE OF AMERICAN ECONOMIC ENTOMOLOGY

INDEX V NOW READY

Price, $4.50

Foreign postage, 50 cents additional

Members in good standing since 1936 will each receive a copy without charge.

BARGAIN SALE ON INDICES I TO IV

Complete set, $10.00

Foreign postage, $2.00 additional

SINGLE VOLUMES

Index I	$5.00
Index II	4.00
Index III	4.00
Index IV	4.00

Foreign postage, 50 cents additional for each volume

COMMON NAMES OF INSECTS

A complete list of the Common Names of Insects, approved by the American Association of Economic Entomologists, has been issued. Copies are available at 50 cents each.

No library is complete without these publications and every working entomologist constantly needs them for reference.

Order from

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Ernest N. Cory, Secretary, College Park, Md.

JOURNAL OF ECONOMIC ENTOMOLOGY

Prices for back volumes and single numbers of the JOURNAL OF ECONOMIC ENTOMOLOGY are as follows until further notice:

Volume 2, 1909	$3.50
Volume 3, 1910	3.50
Volume 4, 1911	3.50
Volume 5, 1912	3.50
Volume 6, 1913	3.50
Volume 7, 1914	3.50
Volume 8, 1915	4.50
Volume 9, 1916	3.50
Volume 10, 1917	3.50
Volume 11, 1918	4.50
Volume 13, 1920	3.50
Volume 14, 1921	3.50
Volume 15, 1922	4.50
Volume 16, 1923	3.50
Volume 17, 1924	4.50
Volume 18, 1925, except Nos. 1 and 2	3.50
Volume 19, 1926, except No. 1	4.25
Volume 20, 1927	3.50
Volume 21, 1928	3.50
Volume 22, 1929	3.50
Volume 23, 1930	3.50
Volume 24, 1931, except No. 1	3.00
Volume 25, 1932	3.50
Volume 26, 1933, except Nos. 1 and 2	3.50
Volume 27, 1934 Nos. 1, 2 and 3 only, each	1.00
Volume 29, 1936, except Nos. 1 and 3	3.00
Volume 30, 1937, except No. 1	3.50

On volumes mailed to foreign countries an extra charge of 50 cents is made to cover postage.

Price of all *other* single numbers, 75c each.

Ernest N. Cory, Business Manager, College Park, Md.

Fumigants

A wide range of effective chemicals with varying degrees of volatility now available

THESE widely used industrial fumigants are suited to protecting products stored in packages or in bulk. Each one combines a low cost per unit treated with maximum effectiveness and minimum hazard.

ETHYLENE OXIDE, a gas, actually destroys all the life stages of insects, including their eggs. Proper application will prevent the possibility of dormant insects becoming active when a treated product is removed from storage. It also devitalizes mold spores and certain bacteria. However, Ethylene Oxide is flammable.

CARBOXIDE fumigant is a gas composed of Ethylene Oxide and sufficient non-flammable carbon dioxide to render the mixture safe under normal conditions. The carbon dioxide also decreases the dosage and time of exposure necessary. Carboxide fumigant is especially suited for treating foodstuffs since it leaves no obnoxious odors, tastes or residues.

ETHYLENE DICHLORIDE is a volatile liquid which can be used alone or as a non-flammable mixture with carbon tetrachloride. This mixture, called "Chlorasol," is valuable in fumigating furs, furniture, rugs, grains and a variety of other commodities.

Other aliphatic chemicals of interest to the research entomologist are available. Additional data will be gladly supplied on request.

The word "Carboxide" used herein is a registered trade-mark.

CARBIDE AND CARBON CHEMICALS CORPORATION
Unit of Union Carbide and Carbon Corporation

UCC

30 East 42nd Street, New York, N.Y.
PRODUCERS OF SYNTHETIC ORGANIC CHEMICALS

McCORMICK INSECTICIDES

STANDARDIZED ANALYTICALLY AND BIOLOGICALLY

McCORMICK'S Pyrethrum and Derris Products are standardized analytically and biologically by graduate chemists and entomologists in the McCormick Laboratories—the most complete testing laboratories in the insecticide industry.

The quality of ingredients used in these insecticides is verified at all times by chemical assay, and their killing power is tested by actual applications to live insects.

Write for free spraying and dusting chart No. 129.

RED ARROW GARDEN SPRAY: The most highly concentrated pyrethrum soap spray on the market.

ROTENONE GREENHOUSE SPRAY: A new product containing 1½% rotenone plus the other active ingredients of derris root, a specific control for red spider.

RED ARROW GARDEN DUST: Contains ¾% rotenone and 30% wettable sulphur. Used as dust or combine with water as wash.

RED "A" SOAP: A liquid neutral potash coconut oil soap with 40% soap content. It is an insecticide itself—also an ideal activator and spreader for use with Red Arrow, reducing the cost of the spray solution.

BLACK ARROW DUST—5000: A combination of very finely ground pyrethrum with other insecticidal factors.

BLACK ARROW—2700: A special pyrethrum dust used only by the mushroom industry.

McCORMICK'S PYRETHRUM POWDER: Ground extremely fine—contains more killing particles per pound—remains suspended in the air longer.

McCORMICK'S DERRIS AND CUBÉ POWDERS: Finest ground powders in the world. Standardized at 4% and 5% rotenone.

McCORMICK'S ROTENONE DUST ¾%: Contains ¾% rotenone, plus all the other toxic ingredients of rotenone-bearing roots.

ROSIN RESIDUE EMULSION: A newly developed spreader and sticker. Used with other insecticides.

THE McCORMICK SALES CO.

Distributors of Pyrethrum and Derris Insecticides

BALTIMORE **MARYLAND**